RIPARIAN RESTORATION AND MANAGEMENT

1 DESCRIPTION OF TECHNIQUE

Riparian zones are defined as the land adjacent to streams, rivers, ponds, lakes, and some wetlands, whose soils and vegetation are influenced by the presence of the ponded or channelized water[1]. Riparian zones include both the active floodplain and the adjacent plant communities that directly influence the stream system by providing shade, fine or large woody material, nutrients, organic and inorganic debris, terrestrial insects, and habitat for riparian-associated wildlife. They are transitions between aquatic and upland habitats and contain elements of both ecosystems. As such, they provide a rich and vital resource to fish and wildlife. Approximately 85% of terrestrial vertebrate species in Washington use riparian habitat for essential life activities[2]. Since the arrival of settlers in the early 1800s, 50% to 90% of riparian habitat in Washington has been either lost or extensively modified[1]. This technique describes methods and factors that influence the restoration and recovery of native riparian plant communities.

Urban development, agriculture, livestock grazing, logging, mining, recreation, and weed invasion impact riparian plant communities by removing or altering vegetation, altering soil conditions, and disrupting natural disturbance cycles (e.g., fire, floods). In addition, channel incision and the diversion or impoundment of water for irrigation, hydroelectric power generation, domestic and industrial water consumption, and similar uses may alter the depth of the water table and patterns of floodplain inundation, which also impact the health and composition of the riparian zone. Techniques to re-establish native plant communities may be passive or active. Passive restoration involves halting those activities that degrade the riparian ecosystem or prevent its recovery (e.g., fencing livestock from the area) in order to foster its natural recovery[3]. Active restoration involves direct manipulation of the landscape, such as grading and planting, in order to accelerate its recovery. Where altered stream flow regimes or channel changes have isolated the stream from its floodplain or created unstable channel conditions, restoration of bank and floodplain vegetation may require channel modification, levee modification or removal, water management modification, or landuse changes to succeed (refer to the *Channel Modification* and *Levee Modification and Removal* techniques and <u>Stream Habitat Restoration Guidelines,</u> Chapter 4.5.2, *Restoring Stream Flow Regime*). Regardless of the specific technique employed, when restoring native riparian plant communities, it is essential to identify and address the cause of riparian degradation, or else restoration efforts are likely to fail. Both active and passive approaches to riparian restoration require years or decades for benefits to be fully realized due to the relatively long growth and establishment periods for many plant species.

Riparian restoration is most effective when riparian areas can be protected from deleterious landuse activities for the long term through land purchase, formal conservation easements, or similar agreements (see the *Dedicating Land and Water to the Preservation and Restoration of Stream Habitat* technique). Other complimentary techniques to consider when restoring riparian zones include removal of floodplain fill, levee removal and modification (see the *Levee Modification and Removal* technique), and reconnecting, restoring, or creating side channels and other floodplain features (see the *Side Channel / Off-channel Habitat Restoration* technique).

2 PHYSICAL AND BIOLOGICAL EFFECTS

Riparian/ floodplain habitats may consist of side channels, off-channel ponds and wetlands, perennial or intermittent streams and springs, and periodically flooded grasslands and forests[4]. These habitats offer feeding, reproduction, and refuge habitat for invertebrates, fish, waterfowl, amphibians, birds, and mammals. In addition, they also have a significant influence on instream habitat. Depending on the type, extent, and density of riparian vegetation, riparian areas may provide the following critical functions to streams, even if they never come in contact with floodwater:

- Provide shade, which helps to moderate stream temperature, providing relatively cool water in summer and warm water in winter. This, in turn, influences the dissolved oxygen content of the water.
- Improve water quality. Riparian vegetation retains sediment and pollutants from overland flow and during flood events, and increases the uptake, storage and release of nutrients into and out of the aquatic environment.
- Retain water during storm events and release it slowly over time, providing longer-term base flow contributions
- Stabilize stream banks and control erosion and sedimentation
- Provide a source of large and small wood to the stream, which can act as sediment storage areas, provide cover and refuge habitat for fish and other aquatic organisms, and create or improve the quality of pools, riffles, backwater, and off-channel habitat
- Provide near-bank cover.
- Provide a source of roughness to the stream.
- Provide leaves, twigs, and insects to streams. These are important food and nutrient sources for fish and other aquatic life.

When riparian areas are accessible to floodwater, they have the additional benefits of reducing the depth of instream flow during high-flow events, thereby lowering the sediment carrying capacity of the stream (and, in turn, bed and bank erosion) and the buoyancy of wood. Vegetated floodplains reduce flood flow velocities so as to limit scour and encourage sediment deposition on the floodplain.

Although some benefits of riparian zone restoration are seasonal in nature, they may be crucial to the survival of species dependant on that habitat during critical periods. See Knutson and Naef[2] and Kauffman et al.[5] for more information on the fish and wildlife benefits associated with riparian zones.

Large-scale riparian restoration projects may require the acquisition and procurement of large amounts of plant materials. Local stocks of native plants will be best suited to site conditions. Some of the required plant materials can be transplanted or cut from adjacent healthy donor sites near the project area. They can also be obtained from nursery suppliers. In either case, source material should be carefully researched to ensure it was legally and responsibly collected (i.e., donor sites were not adversely affected), and that material is disease-free and adapted to local site conditions. More information on the potential impacts of this technique is provided in the *Risk and Uncertainty* section.

3 Application of Technique

Riparian restoration may be employed as a stand-alone technique or used in conjunction with other stream restoration and enhancement efforts. However, it is only applicable where short- and long-term landuse, management activities, and site conditions are compatible with the establishment and growth of the desired riparian vegetation. Riparian restoration and management may be undertaken on sites ranging from narrow stream fringes characterized by sharp transitions to upland habitat to wide riparian corridors with gradual transitions to adjacent uplands. Riparian restoration can be implemented on small sites with limited budgets. However, the benefits to fish, wildlife, water quality, and the physical condition of the stream are much greater when applied on long continuous lengths of stream and across entire floodplain widths, as opposed to applying it on isolated patches.

Use of passive land or water management changes alone to improve riparian condition will be most successful where land uses such as poor livestock management, recreational foot traffic, logging, or mowing have degraded but not entirely eliminated desired vegetation and soil structure. Sites affected by more severe land uses such that they are characterized by sparse or weedy vegetation and disturbed soils, may require active restoration including weed control, site preparation, supplemental planting, plant maintenance, or silvicultural treatments. If the stream channel is unstable (e.g., it is actively aggrading, incising, or segments are in hydrologic transition due to recent landuse changes), the cause of the instability needs to be assessed and addressed prior to active riparian restoration or else new plantings will likely be lost to bank erosion or water table changes. However, passive approaches to riparian restoration may still be appropriate.

Since a well-established riparian corridor can buffer a stream from adjacent land uses and promote channel stability, it should be incorporated into all stream restoration work. This includes construction or modification of channels (see the *Channel Modification* technique); installation or removal of bank protection (see the *Bank Protection Installation, Modification, and Removal* technique); reconnection, restoration, or creation of side channels and other floodplain habitats (see the *Side Channel / Off-Channel Habitat Restoration* technique); and addition of large wood to the stream or floodplain (see the *Large Wood and Log Jams* technique).

4 RISK AND UNCERTAINTY

4.1 Risk to Habitat

Risks to existing habitat are limited in riparian restoration, since it is generally implemented where there is little or no natural habitat value. However, in some instances, potential risks to existing habitat include:

- Disturbance of existing habitat during weed control due to herbicide drift or large scale removal of existing vegetation in preparation to planting
- Disturbance to adjacent habitat to gain access to project areas
- Loss of existing habitat where plant material is salvaged for transplant
- Introduction of disease or pests by plants that are imported to the site

These and other risks to habitat must be considered and avoided where possible through careful planning. Where such disturbances are unavoidable or could potentially occur during the course of project implementation, efforts to restore or replace damaged habitats should be implemented, either as part of the original project plan or as a contingency measure.

4.2 Risk to Infrastructure and Property

Riparian restoration and management may pose an increased risk of flooding or damage to infrastructure and other property located in the floodplain when undertaken on a large scale. This can occur when the restored vegetation increases the hydraulic roughness of the streambank and floodplain, thereby raising floodwater elevations and possibly increasing channel sinuosity[3]. While riparian restoration is generally beneficial, it is important to understand, acknowledge, and minimize the potential risks.

4.3 Risk to Public Safety

Since large riparian planting projects that restore woody vegetation across the floodplain can increase the risk of flooding, public safety may be at risk. This risk may be minor if the affected area is only seasonally or occasionally used, such as a park, or it may be substantial if any infrastructure is affected. Chemical weed control may also pose a risk to the public.

4.4 Uncertainty of Technique

Riparian vegetation can rapidly reestablish under proper landuse and site conditions. However, failure to identify the numerous biological and physical site factors that affect riparian plant communities can hamper the success of recovery efforts. Biological risks that can limit establishment or recovery of native plants include weed invasion, small and large mammal browsing, beaver harvest, trampling or rubbing by livestock, deer or elk, and plant disease or pest infestations. Physical factors that can limit plant growth include drought, low water table, excessive or unanticipated inundation regimes, sediment and related flood flow deposition, scour and erosion, and overly compacted, saline, shallow, or disturbed soils. Vandalism, destruction from mowing, and unregulated uses such as off-trail motorized biking and unmanaged camping may also be a problem in some areas. Only some of these physical and biological constraints to vegetation establishment can be controlled.

There is also a risk that the desired plant community will not recover and mature to the desired state and provide the anticipated benefits within the desired time frame. Even under optimal conditions, native vegetation can take years to establish and may take decades to mature or cycle through the several seral stages that ultimately will provide all the desired benefits. Using supplemental techniques that provide certain benefits within a shorter time frame can reduce this risk. For example, if riparian restoration is undertaken to provide a long-term source of wood to the stream and floodplain, placing large wood directly in the stream or floodplain will provide immediate, though short-term benefits while the riparian vegetation matures.

5 Methods and Design

Riparian restoration may be accomplished using passive means that involve halting or modifying deleterious landuse and water management practices that degrade the riparian plant community or prevent it from recovering. Alternatively, restoration may involve active measures ranging from supplemental planting to extensive site preparation and short- and long-term maintenance. Major preparatory work such as channel modification, levee modification or removal, and restoration of stream hydrology may also be required to restore conditions that make recovery possible. This work may be needed to address channel stability, floodplain connectivity, or water availability (e.g. water table too low or too variable to support the establishment and growth of riparian vegetation).

Riparian restoration requires a thorough understanding of the role that natural disturbance plays in affecting plant colonization and succession patterns such that diverse and productive riparian ecosystems are maintained. In addition, consideration must be given to site-specific conditions such as soil type and exposure to drought, floods, sediment deposition, wind, and sun.

5.1 Data Collection and Assessment

Successful planting requires sufficient planning, site evaluation, monitoring, and maintenance to ensure that long-term goals are met. Plant materials must be carefully selected with regard to site conditions and constraints. The list of steps below is the recommended sequence for most riparian revegetation plans. Each step in the sequence is discussed in more detail in this technique. If any step is left out or not completed due to budget constraints, the success of the project is less certain.

- Conduct a site review including nearby analogs of the desired future condition;
- Identify site constraints;
- Identify needed changes in land management
- Develop design criteria;
- Select plant species;
- Select plant-material types (e.g., woody, herbaceous, bare-root, seed, potted);
- Determine planting density and layout;

- Schedule timing of plantings;
- Consider site-preparation requirements;
- Determine planting techniques; and
- Define procedures to monitor and maintain project

5.1.1 Site Review

Riparian areas are often characterized by diverse site conditions. Flowing water sorts sediments, creating floodplain soils that are stratified both vertically and horizontally. Varied floodplain topography creates a gradient of depth and duration of flooding. Every plant has an optimal position along this hydraulic gradient. The hydraulic gradient, coupled with variations in soil structure, vegetation, and topography create a complex and dynamic network of habitats throughout the floodplain[6]. As a result, site reviews are essential to ensuring site conditions match the needs of the selected plants.

The site review should include the project area and a vegetative community reference site, preferably in the same or a nearby watershed with similar site conditions, similar flood history and hydrology. At a minimum, the following information should be collected:

- *Plant Distribution/Colonization* – note the distribution of dominant woody and herbaceous species (including weeds) relative to river stage, hydrology and shade, and which plants are colonizing freshly deposited soils. Look for and identify any good sources for local cutting collection and/or plant salvage. Usually this must be done at a reference area since the area you are working on often doesn't have any plants or it has introduced or invasive plants.
- *Shade* – observe and note how canopy cover will affect light availability for new plants.
- *Lower Limit of Perennial Vegetation* – determine the lowest bank elevation that will support perennial vegetation. This is most accurately determined on gradually sloping banks, where an easily observed continuum exists, ranging from unvegetated channel to annual plants to perennial plants. If possible, note how this elevation relates to river discharge. See Information Series 16, Riparian Planting Zones, Riparian/Wetland Project, at http://www.Plant-Materials.nrcs.usda.gov/idpmc/
- *Depth to Groundwater* – ideally, this is determined using test pits or monitoring wells; but, in the absence of such tools, it is often estimated using the elevation of late-summer base flow, although this is not always accurate at the furthest area from the water surface.
- *Soils* – describe existing soils on different bank and channel features such as bars and overbank-deposition areas. Note the soil texture (e.g., sandy, rocky, clayey, organic). Note whether soils are well drained (gravelly or sandy) or poorly drained (clayey or organic), how moist the soil is, and whether it is friable or highly compacted by livestock or heavy-equipment operation. Look for cut banks that identify soil profile by depth. Are shallow soils or till present? Additional information that can be helpful but is not often collected includes soil pH, salinity and nutrient status. This information can be obtained by sending a sample to a soil lab or by testing it with a home soil test kit.

- *Human/Wildlife Use of the Site* – note whether there is existing or a potential for human and animal foot traffic, recreational river use, grazing, deer and elk browsing, beaver activity, or other potential impacts to vegetation and soil.
- *Hydrology* – check to see if portions of the site periodically flood. If so, attempt to determine how often and for how long. Look for physical indicators of high flow, such as sediment deposition, wood, and trash.
- *Geographic Characteristics* – determine the elevation, slope and aspect of the site. Plant species harvested for revegetation projects that come from high elevations on the slope may not grow well at low elevations. Some species are more adapted to steep slope conditions and provide greater resistance to slope erosion than others. South-facing slopes are typically much drier than north-facing slopes.

5.1.2 Site Constraints

Early in the planning process, identify potential factors that may limit successful revegetation. While most site constraints are biological or physical in nature, they may also be related to project budget and management or to the scheduling of construction activities. Often, early recognition of site constraints can lead to creative solutions that may increase plant survival, simplify construction and possibly save money.

Below are some possible site constraints, many of which are specifically related to natural riparian processes.

- Weed and grass competition for water, sun, and space;
- Heavy shade;
- Direct sun exposure;
- Over-compacted soils;
- Overly drained soils;
- Poorly drained soil;
- Deep summer water table;
- Shallow soils/bedrock;
- High amounts of sediment deposition;
- Large flood events expected soon after planting;
- Potential ice flows/ damage;
- Poor native-species availability;
- Soil compaction due to heavy foot traffic (human or animal);
- Nearby seed source of aggressive weeds
- Construction sequencing conflicts;
- Livestock, deer and elk grazing/trampling/browsing;
- Heavy beaver damage;
- Tide-influenced hydrology;
- Limited site access;
- Herbicide drift from adjacent agriculture;
- Incompatible mowing and pruning activities (common at golf courses and near power lines);
- Rodent problems (common in sunny open fields);
- Extended inundation;
- High soil salinity (common in arid areas that are irrigated);
- Dam-influenced or otherwise modified hydrology;
- Reduced riparian/stream interaction
- Insufficient maintenance budget;

Consider also landowner desires and zoning requirements. Some riparian treatments may be appropriate in one setting and not in another. For example, the allowable height or species of vegetation may be limited due to its proximity to utilities, to address safety concerns, or to preserve views.

When installing structures such as fences, offsite watering facilities, irrigation systems, and other features in the riparian zone, consider the effects that high water events and flood flows may have. This would include deposition of sediments and debris as well as scour. It may be best to locate these structures outside the flood prone area whenever possible.

5.2 Changes in Landuse or Water Management

Changing landuse or water management to foster natural recovery of riparian vegetation or to complement revegetation efforts includes cessation or modification of current activities that limit the species, diversity and extent of the riparian community. Such activities may include, but are not limited to, livestock grazing, timber harvest, mining, agriculture, mowing, road building, earth moving, filling, construction of buildings or other facilities, recreation, or any activity in the watershed that modifies the natural hydrology of the site. Stopping or modifying these activities to reduce adverse effects on riparian function may require purchase or lease of the land (see *Dedicating Land and Water to Stream Habitat Preservation and Restoration* technique) or water rights, regulation of development, or a legally binding commitment by the landowner (e.g., a conservation easement. Restoration of riparian habitats through changes in landuse and water management requires a long-term commitment to be effective. This commitment should also extend to maintenance and repair work whenever applicable.

If relying on landuse and water management change as a stand-alone treatment (i.e., without supplemental planting), consider the likelihood and time period for natural regeneration of desirable vegetation and the potential for weed invasion. This is particularly important if the landuse change involves grazing removal. Eliminating livestock can result in weed proliferation if not adequately anticipated with an approved weed control plan in place. As described in Briggs[7], factors that affect the natural distribution and propagation of riparian plant species include:

- Spatial and temporal variation in the “seed bank”. Is there a natural source of seeds of the desired plant species available to the site? This may be a difficult question to answer. Factors influencing seed availability include the composition of the buried seed bank, proximity and abundance of desirable and undesirable species to the site, abundance and characteristics of seeds produced by the species, and dominant seed dispersal mechanisms (e.g., animals, wind, water). Build-up of non-native weeds may prevent native seeds from sprouting and becoming established. Vegetative propagation (sprouting from stems, lateral roots, or trunk bases) is also a common form of regeneration for many riparian plant species and could be important in the recovery process.
- Variation in scour and deposition. These affect the ability of seeds and plants to germinate and establish, and the distribution of water-borne seeds.
- Inundation depth, frequency, extent, and duration. Many plant species are

adapted to, and depend on, flooding for propagation. Flood disturbance can revitalize riparian ecosystems by producing sunny, bare soil sites that lack competition from other plants and have high moisture availability. Such sites are ideal for the establishment of colonizing vegetation such as red alder, black cottonwood, and willow species.

- Elevation, drainage area, geology, and flow regime. These affect seed availability and dispersion.
- Characteristics vital to species' germination and growth, including water availability, soil condition, physical and biological constraints, flow regime.

Knutson and Naef[2] recommend specific best management practices to control or limit the adverse impacts to riparian habitats from various landuse activities, including agriculture, grazing, forest practices, roads, recreation, and urban development.

5.3 Recommended Minimum Width of Riparian Habitat Areas

The width of the corridor to be restored or enhanced will be site specific, dictated by budget constraints, land ownerships, infrastructure, valley width, and similar variables. But whenever possible, riparian zones should be wide enough to protect and preserve fish and wildlife habitat and to connect riparian habitat to other adjacent habitats including upland forests. The Washington Department of Fish and Wildlife recommends the following minimum widths for riparian habitat associated with streams[2]

Riparian Restoration and Management Table 1: Recommended Riparian Habitat Area widths. Source: K. L. Knutson and V. L. Naef. *Management Recommendations for Washington's Priority Habitats: Riparian*[2].

Stream Type	Recommended Riparian Habitat Area Width (feet)
Types 1 and 2 streams ("Shorelines of the State" and channels with widths greater than 20 feet)	250
Type 3 streams or other perennial or fish bearing streams that are five to 20 feet wide	200
Type 3 streams or other perennial or fish bearing streams that are less than five feet wide	150
Type 4 and 5 streams or intermittent streams with low mass wasting potential	150
Type 4 and 5 streams or intermittent streams with high mass wasting potential	225

These widths are applied to each side of the stream, starting at the ordinary high water line. However, if the stream reach is located in a broad, alluvial valley and able to migrate across the valley, these width measurements begin at the edge of the channel migration zone. The following are important additions to the recommended Riparian Habitat Area widths.

- If the 100-year floodplain exceeds these widths, the Riparian Habitat Area width should extend to the outer edge of the 100-year floodplain.
- Larger widths may be required where priority species occur (refer to Appendices C and D of Knutson and Naef [2] for specific recommendations). See also Morrison[8].
- Add 100 feet to the riparian habitat area's outer edge on the windward side of riparian areas where existing trees are susceptible to blowdown.
- Extend the Riparian Habitat Area widths at least to the outer edge of unstable slopes along Type 4 and 5 waters in soils of high mass wasting potential.

The widths recommended in **Riparian Restoration and Management Table 1** are intended to maintain fully functional riparian ecosystems and to provide sufficient habitat to meet the needs of fish and wildlife. Riparian habitat functions that were considered in making these recommendations include control of stream temperature, provision of large wood and other organic material to the stream system, regulation of stream flow, filtration of sediments and pollutants, erosion control, microclimate maintenance, and wildlife habitat. Other widths may be sufficient to maintain a subset of these functions.

5.4 Planting

If modifying landuse or management alone is not sufficient to recover the riparian zone, a planting plan will need to be developed and implemented.

5.4.1 Design Criteria

While not necessary for all projects, revegetation planning should generally begin with development of design criteria. Design criteria are specific guidelines that quantify desired performance attributes to meet project objectives. A general revegetation guideline or objective might be "to provide habitat" or "to provide erosion control," whereas a design criterion might be "to provide overhanging shrub cover along 50 percent of bank within three years." Design criteria for vegetation should specify requirements for habitat needs, size of material, species diversity and erosion control. While specific design criteria are not always necessary, the development of objectives is the most important part of developing a plan. The development of clear objectives will help keep the project on track by limiting actions to those that will help meet the objectives. Refer to Stream Habitat Restoration Guidelines, Chapter 5.3.4, *Design Criteria* for further information.

5.4.2 Plant-Species Selection

Plant species selection must be tailored to site conditions. The soil, light, and moisture requirements of individual plant species must match those occurring at the site. In an unpublished 2001 study conducted by WDFW on ten channelized stream restoration projects in western Washington[9], the most common cause of plant mortality was poor plant species selection and distribution. Other controllable causes of plant mortality observed in the study included inadequate site preparation and/or maintenance (watering and weed control), inadequate protection from animal damage, poor plant stock quality, and improper planting techniques and timing. When planting in riparian zones, the most common cause of failure is inadequate assessment of available moisture and inundation patterns (Chris Hoag – personal communication).

To maximize benefits to native fish and wildlife species, use only native plant species. Native plants are adapted to local climates and disturbance regimes (e.g., fire, flood, landslides), compete well for survival on native soils, are resistant to local insect infestations, and provide food and habitat for native wildlife. Use the reference site as a tool to aid in designing a planting plan for the project area, but be sure to consider the role of succession in achieving the reference plant community. For instance, a nearby site with similar conditions to the project area might be dominated by a relatively mature stand of western red cedar trees and an understory of salmonberry. But planting those same plants at a project site that is has just been denuded by construction and is fully exposed to sun and wind will likely result in high plant mortality unless the plants have access to lots of moisture. Cedar seedlings and salmonberry establish best in shady conditions. Colonizing species, such as Douglas fir and red alder, will be better adapted to the extreme temperature and moisture variability of bare exposed soil.

Historic plant communities at the site are also helpful when developing planting plans. Again, the role of succession must be taken into account. Also, if the watershed has been significantly hydrologically modified (i.e. heavily urbanized, downstream of a reservoir, or drained), the historic plant community may no longer be able to survive. In these areas, re-establishment of historic vegetative communities will not be possible and other native vegetation or even non-native vegetation may have to be used.

Riparian Restoration and Management Table 7 provides a list of native species one might consider using on riparian restoration projects. This list is not exhaustive, but it does provide helpful information to consider during the plant selection process. Consult plant guides, local references[10 11] or native-plant nurseries for further information on specific plants. There are over 40 native-plant nurseries in the state of Washington[12]. As with any purchase, when choosing a source of plant material, assess the quality of the plants; cheaper is not necessarily better. Plants grown in western Washington may not do well on the east side and vise versa. Make sure you know where the plants were collected, and match the elevation, soils, latitude, etc. as much as possible to your planting site. Usually, nursery staff can assist in plant selection.

Plant species should be selected with an emphasis on the following:

- Suitability for anticipated climate, hydrology, elevation, soils and constraints of the planting site;
- Reasonable availability in desired quantity (either from nurseries or a local source);
- Probability of successful establishment (based on best available experience or information);
- Desired growth form or shape and size (as specified in design criteria)
- Ability to achieve desired plant diversity (as specified in design criteria).
- Ability to provide desired fish and wildlife benefits, such as food and shelter habitat (as specified in design criteria)

Additional considerations include:

- *Diversity*. Natural riparian plant communities consist of a variety of species and successional stages, which is important to support diverse fish and wildlife populations. In naturally forested areas, a mix of deciduous and coniferous trees exists. Deciduous trees are more abundant in frequently or recently disturbed areas, whereas conifers are generally more abundant in vegetative communities that have more mature or advanced seral conditions. In naturally non-forested areas, the dominant vegetation may be shrubs, or grasses and forbs[1]. Planting a variety of species ensures the highest likelihood of project success. Monocultures are susceptible to total failure when exposed to disease or unfavorable site conditions. Consider planting a mix of fast- and slow-growing plants, deciduous and evergreen.
- *Multiple canopy layers*. Multiple canopy layers provide more habitat niches to support diverse wildlife populations. Mature, naturally forested areas support at least three of the following canopy layers: humus, grass/forb, short shrubs, tall shrubs, small trees, and large trees. Naturally non-forested riparian areas may support fewer layers[2].
- *Genetics.* Choosing native plants grown with seed or cuttings collected from sites in local watersheds will preserve the genetic integrity of the local stock and will have the highest likelihood of success.
- *Exposure tolerance to*:
    - *Sun, wind and low soil nutrients*. When choosing plants for a disturbed streambank or riparian zone, consider each plant's role in succession.

Pioneer species such as red alder (*Alnus rubra*), black cottonwood (*Populus trichocarpa*), and willow (*Salix* spp.) are naturally tolerant of extreme, adverse conditions, such as low soil-nutrient levels, moisture stress, and full sun and wind exposure. Alternatively, some native conifers, such as western red cedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*), form late-succession forests and establish best under shady, relatively protected conditions[13]. Planting such seedlings in direct-sun locations often fails. Success of late successional species may be substantially improved if planted after a nearby shrub or tree layer develops a canopy, offering at least partial shade.

- *Grazing*. Planting species capable of stump sprouting or suckering from roots (identified in **Riparian Restoration and Management Table 7** by a "†") will reduce long-term grazing impacts.
- *Flooding*. Certain species are better adapted than others to periodic inundation and sediment deposition. The degree of tolerance varies among species. For instance, willows can grow in frequently flooded areas (even within the active channel), whereas big leaf maple or western hemlock are most often found on flood prone surfaces above the 10-year return interval flood level.

The plant community will likely change over time from the original planting plan as a result of disturbance, succession, and subtle variations in the topography, soil structure, and moisture regime. Some of the planted stock will likely flourish at the expense of others. Scour, deposition, and inundation will be detrimental to some species, but pave the way for colonization by others in the vicinity.

5.4.3 Plant-Material Types

Plant-material types include cuttings, seed, containerized, bare-root stock, and ball and burlap stock. They are further classified into herbaceous and woody plant categories. Base the selection of specific woody or herbaceous plant-material types on design objectives or design criteria, site conditions, and site constraints. Most projects use a combination of woody and herbaceous plant-materials.

5.4.3.1 Woody Plant Material

Woody plants, which include both shrubs and trees, are widely used in riparian restoration projects to provide bank stability, habitat and aesthetic appeal. Their roots tend to be strong and deep, mechanically reinforcing soils by adding tensile strength.[14] Large riparian trees contribute large woody material to streams when they topple, and all woody plants provide shade and cover to streams. Undercut tree and shrub roots provide excellent fish habitat, especially the roots of mature cedar, hemlock, and spruce. Shrubs with their multiple, flexible stems dissipate stream energy and encourage sediment deposition rather than scour. Common, woody plant materials are discussed below.

Cuttings. Cuttings consist of harvested stems of dormant shrubs and trees. They are capable of developing both roots and shoots if planted in proper conditions. A short list of riparian shrubs or trees native to Washington can reliably and consistently root from cuttings. For the best chance of success, cuttings must be harvested during the dormant season, preferably fall or spring[6], and planted within days of collection. Expect up to 80 per cent mortality if the buds on the cuttings have begun to open as plant respiration will begin prior to root development and limit the degree to which new roots can form, if at all. By far, willow species (*Salix* spp.) are the most commonly used and successful cuttings. Other species commonly used in Washington with good success include red-osier dogwood (*Cornus stolonifera*) and black cottonwood (*Populus balsamifera trichocarpa*). Species that are less commonly used, but root well from cuttings, include salmonberry (*Rubus spectabilis*), elderberry (*Sambucus* spp.), Pacific ninebark (*Physocarpus capitatus*), mallow ninebark (*Physocarpus malvaceous*), black twinberry (*Lonicera involucrata*), Nootka rose (*Rosa nutkana*), golden current (*Ribes aureum*), wax current (*Ribes cereum*), syringa (*Philadelphus lewisii*) and spirea (*Spiraea* spp.)[7]

Not all of the species listed above are appropriate in live-stake applications due to their relatively small, flexible branches, but they are appropriate as components of fascines and brush layers. Few other riparian shrubs or trees native to Washington reliably and consistently root from cuttings. Cuttings are popular in bank-stabilization projects because they are inexpensive and can be collected in long lengths capable of accessing moist soils in the vicinity of deep (10- to 12-foot) water tables. Whether installed as live stakes, fascines, or brush mattresses, cuttings provide excellent erosion control and bank stabilization. More detail on cuttings is provided later in this technique under *Planting Techniques*.

<u>Containerized</u>. Containerized plants are nursery-grown plants in any one of dozens of different sizes and shapes of containers. They are distinguished from most other types of plant materials by their well-developed soil/root mass, allowing planting to occur throughout much of the year, provided adequate water is available. If plants are irrigated, they can be installed in the dry summer months, which is an advantage when construction occurs during summer low-flow. Another advantage of containerized plants, especially in contrast to cuttings, is that many riparian plant species native to Washington State are commercially available in this form. Conifers such as cedar, spruce and hemlock are usually acquired as containerized plant material. On the down side, the root systems of containerized plants are initially established within commercially available potting soils. These soils typically have characteristics much different than that of the planting site and often the root systems of the plant do not readily leave the potting soil despite removal of the container and several years of growth. Care must be exercised during planting to encourage root migration into surrounding native soils. More detail on this is provided later in this technique under *Planting Techniques*.

Although conventional landscaping nurseries typically provide containerized plants in one-, two-, or five-gallon containers, some native-plant nurseries make use of a much wider array of containers better suited to streamside conditions. For example, a deep but narrow container known as a tubeling or plug has dimensions of approximately one inch wide by six inches deep. The greater depth-to-width ratio of the tube provides the plant with better resistance to pullout caused by flowing water and better access to deep, moist soil than conventional nursery containers. Other innovative containers include, but are certainly not limited to, 14-inch-deep treepots®, PVC pipe four to six inches wide by one to two feet long, biodegradable burlap "socks" and biodegradable coir (coconut-husk fiber) containers.

<u>Bare-root</u>. Bare-root plant material is a nursery-grown, woody plant-material widely used in riparian restoration. Bare-root plants consist of rooted plants sold with the soil removed and packaged with damp sphagnum moss or sawdust and sold in bundles. Bare-root plant material generally requires smaller planting holes than comparatively sized containerized plants because you don't have to make room in the hole for soil packed around the roots. Although much less expensive (one-tenth the cost of container stock), bare-root plants have a lower survival rate if stored or planted incorrectly. Bare-root plants require special handling so that their roots are not exposed to sun or wind for more than 30 seconds to a minute. This requires keeping the bare-root plants covered and their roots moist at all time and not delivering more plants to the site in a day than can be planted. Bare root plants must be planted in a dormant condition. On the other hand bare-rootstock is planted directly in soils native to the site and roots more readily migrate out of the planting hole and into the surrounding soil. With proper storing and handling survival rates can be 80 to 90%. Bare-root plants are becoming increasingly available, both in number and species diversity, at native-plant-material centers, nurseries and local conservation districts. Locally collected material is harder to find, but some nurseries can accommodate special requests with advance notice. Contract growing is an increasingly available option and often does not cost more than regularly stocked bare root plants, but will need to be ordered 12 to 18 months prior to planting. The main limitation of bare-root plants is their narrow planting window (late winter/early spring dormant season), which will require proper planning and, possibly, use of a larger planting crew.

<u>Ball and Burlap</u>. Ball-and-burlap plants consist of mature trees and shrubs ranging from six to 12 feet tall. Plants are shipped from nurseries with their roots "balled-up" and wrapped in burlap and wire. Their large size makes ball-and-burlap plants less likely to become stressed and die as a result of animal damage and weed competition. Their large size also adds an element of structural diversity to a revegetated area. However, ball-and-burlap plants are considerably more expensive than other plant materials and their large size and bulk make handling difficult, requiring guy wires and staking for stability during the first one to two years after planting. They also provide many of the structural requirements much faster like shade, fish habitat, cooling, source of large wood, etc.

<u>Salvaged</u>. Ideally obtained on-site, salvaged shrubs and trees are those that otherwise would be destroyed or disposed of during the construction phase of a stream restoration project or another nearby construction project, but are instead salvaged and replanted. If carefully coordinated, excavators or tree spades can cost effectively transplant a large number of seedlings, saplings and, sometimes, mature shrubs and trees. Frequently, this type of large equipment can provide an entire plug of mixed vegetation including the target shrub or tree and its associated herbaceous layer. In addition to great cost savings (provided equipment and transportation costs are low), salvaged plantings can provide immediate benefits to bank stability, structural diversity, cover and aesthetics compared

to smaller plant materials. Their large root mass may also make them resistant to flood flows.

When salvaging plant material, keep in mind that salvaged plants are an assemblage of living stems, crown, and roots excavated as a single unit. In addition, the soil bound by the roots is considered a component of the salvaged plant[8]. Consequently, successful salvage requires excavation of a sufficient portion of the soil root mass to support the aboveground foliage. On small plants, the entire root mass may be obtained with the use of a shovel or backhoe. On larger shrubs or trees, excavators and tree spades are required; however, some trees may have root masses too extensive to allow for salvage and transplant. When salvaging plant material, keep in mind that the larger the plant being transplanted, the lower survival rate it will have. The root systems on large plants are more likely to get damaged during the process, and the damaged root system may not be capable of supporting the relatively large, above-ground portion of the plant during the first growing season following transplant. To reduce the shock of transplanting, dormant plant materials are preferred, but if flood or winter conditions require non-dormant salvage, irrigation may be needed to maintain soil moisture until late fall[8]. Pruning woody stems and branches may help reduce drought stress. Willow clump plantings can be planted with the root systems and collar much deeper than the soil surface (as much as 3-4 feet below the surface). This allows the roots to be placed in the saturated zone rather than above it.

According to the Thurston County Master Gardener Foundation[7], native plants that are easily salvaged in western Washington include:

Vine maple (*Acer circinatum*),
Bigleaf maple (*Acer macrophyllum*),
Red alder (*Alnus rubra*),
Beaked hazelnut (*Corylus cornuta*),
Oregon ash (*Fraxinus latifolia*),
Nootka rose (*Rosa nutkana*),
Indian plum (*Oemleria cerasiformis*),
Pacific ninebark (*Physocarpus capitatus*),
Douglas fir (*Pseudotsuga menziesii*),
Cascara (*Rhamnus purshiana*),
Clustered rose (*Rosa pisocarpa*),
Red elderberry (*Sambucus racemosa*),
Snowberry (*Symphoricarpos albus*),
Western red cedar (*Thuja plicata*)

There isn't a similar document for eastern Washington, but the following species, native to the eastside, are likely easily salvaged:

Red alder[12]	Thinleaf alder[15]	Snowberry
Nootka rose	Wood's rose	Douglas fir
Willows	Western red cedar	

Seed. Seed is a commonly used and inexpensive material for revegetation projects. However, the establishment of woody plants from seed alone can be difficult, and is often less successful than efforts using other types of woody plant materials. Whenever possible, seeding should be combined with materials such as cuttings, bare root, or containerized plants. On some sites, there may be interest in experimenting with western red cedar using direct seeding, as discussed in the Soil Rehabilitation Guidebook[16]. Similarly, most cottonwood species rely on seed distribution and moisture regimes associated with high flows to be successful, and therefore can be appropriate for seeding depending on site-specific conditions.

5.4.3.2 Herbaceous Plant Material

Herbaceous plants are grass and grass-like plants including rushes, sedges, ferns, legumes, and forbs. They have fine-textured roots that grow six to 24 inches deep, depending on species, soil type and site hydrology. In contrast to woody plants, most herbaceous plants form dense cover over the soil surface, although some species tend to be more clumped. Their fine root mats and dense cover provide excellent soil reinforcement and protection from surface soil erosion. Unlike some woody species, the flexible stems of herbaceous plants bend under flood flows, providing high-flood conveyance.

Seed. Seed is the most common type of herbaceous plant material because it is relatively inexpensive; and, if planted properly, can quickly establish itself as a short- or long-lasting ground cover. In reconstructed streambanks, seed is generally spread by hand or with a mechanical seeding device, and it is covered with a temporary erosion-control fabric to protect the seed from washing out during flood events. Erosion control fabric is expensive to apply to large areas, but is necessary where overbank flows are anticipated immediately following floodplain reconstruction. Care must be exercised in the selection of erosion control fabrics as fabrics with fine openings or fabrics not held tightly against the soil surface will prevent emerging leaves and stems from penetrating the fabric. Many erosion control efforts fail in this manner and the lack of visible vegetation is often initially blamed on poor germination until inspection under the fabric reveals seedlings that died in their efforts to penetrate the fabric. Larger riparian and floodplain restoration projects may use less expensive techniques such as sterile, seed-free straw or cellulose fiber mulch in less frequently flooded areas. Mulches can be used where necessary to protect newly sown seed from moisture loss, wind displacement, and competition from weeds. Seed is also available in pre-seeded erosion-control mats. This product may be beneficial on steep slopes where it would otherwise be difficult to place seed. However, pre-seeded mats are relatively expensive, and their use often results in spotty vegetative cover. Seed can also be applied using hydroseeding methods; however, hydroseeding is not recommended for streambanks or floodplains subject to frequent flooding because it offers little protection against flowing water. Some suggestions for selecting the most suitable mix of seed are discussed later in this technique under *Planting Techniques*. In all cases, the need to protect a seeded surface with fabric should be weighed against the acceptable risk of loosing all placed seed and significant soil erosion if the floodplain is inundated prior to establishment of vegetation.

When only native grasses and herbs will be allowed in replanting programs on some lands (i.e. National Park Service) and they are not available, sterile seeds can be used. Sterile grasses, especially, are becoming increasingly available.

<u>Containerized</u>. Nursery-grown herbaceous species are widely available in containers similar to those described under the previous discussion on *Woody Plant-Material Types*. Keep in mind that very small plugs are difficult to plant, grow and maintain. NRCS research[17] shows that the best results were obtained using $24in^3$ plugs. This size will have a good root system and above ground biomass to allow rapid establishment allowing it to compete with weeds and not drown during flood events. For sites requiring local material, contract growing of herbaceous species is widely practiced. If nurseries are supplied the local seed, contract-grown plug costs are often less than regular stock costs. Plugs are generally planted in a non-dormant state and have a wider planting window than bare-root stock.

<u>Bare-root</u>. Emergent, wetland, herbaceous plants such as bulrush (*Scirpus spp*.) are available in bean-sized, bare-root fragments. Easy to install and far less expensive than containerized plants, streambank and riparian zone plantings of bare-root herbaceous plants are appropriate. Growth from a bare-root fragment will be much slower than from a containerized plug and like woody bare-root stock, herbaceous bare-root stock must be planted in their dormant season (late winter to early spring) and may require supplemental irrigation.

<u>Salvaged</u>. Salvaged sod, if available, is an outstanding type of herbaceous plant material. It has a dense soil/root mass that is relatively resistant to erosive forces; it establishes quickly; it's cost effective, and it makes use of materials that may otherwise be discarded. Salvaging and transplanting sod requires an excavator or other specialized, heavy equipment. Sod should be salvaged when the underlying soil is moist. Moist soil, even soils temporally moistened through irrigation, is necessary as dry soils result in sod blankets that break up during handling.

<u>Pre-vegetated Mat</u>. Similar to salvaged sod in terms of its advantages, pre-vegetated coconut mats resemble conventional turf sod. The mats have dense root systems that quickly penetrate the soil once installed. The coconut mat provides temporary erosion control until the vegetation gets established. Available from some Washington native plant nurseries, these products can be a low-risk (but expensive) means to quickly establish herbaceous cover.

5.4.4 Plant Density and Layout

Planting densities for streambanks and floodplains are determined on a "plant per linear foot" basis, if planting on a narrow strip along the water's edge, or on a "feet on center" basis if planted on larger or wider areas. **Riparian Restoration and Management Table 2** provides general density recommendations for different plant materials. Remember that these recommendations are only a starting point for planning and may need to be adjusted depending upon project budget, erosion-control requirements, probability of survival, role of vegetation in establishment of hydraulic roughness and anticipated time to maturity.

Riparian Restoration and Management Table 2: Recommended Densities for Plant Materials.

Plant Material Type	**Planting Density (highly site dependent)**
Cuttings	1-2 ft on-center or planted in bundles, dense rows, brush mattresses[18] or other bioengineering method
Containerized herbaceous plantings	1.5 to 2 ft on-center
Containerized shrub	3 ft to 5 ft on-center depending on the species
Containerized tree	10 ft on-center (435 plants per acre). This is species related. Too close and the plants can be overstressed.
1.5inch-diameter stem, ball & burlap tree	20 ft on-center
Bare-root stock	5 to 10 feet on-center for shrubs; 10 to 20 feet on center for trees
Seed mix	Seeding rate depends upon species

A small increase in planting density can increase the number of plants per acre substantially. For example, decreasing plant spacing from five feet on-center to three feet on-center increases plants per acre from approximately 1,792 to 4,840. **Riparian Restoration and Management Table 3** provides planting-density conversions.

Riparian Restoration and Management Table 3. Planting density equivalencies.

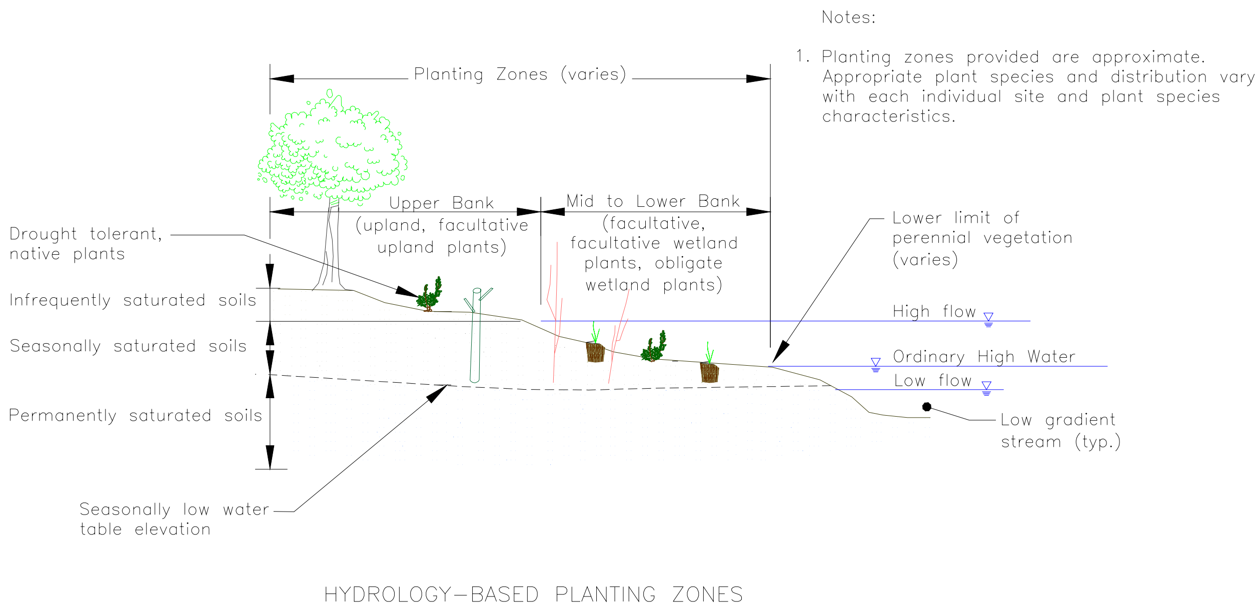
Ft on center	**Sq. ft per plant**	**Plants per acre**
1	1.0	43,560
2	4.0	10,890
3	9.0	4,840
4	16.0	2,722
5	25.0	1,742
10	100.0	435
15	225.0	193
20	400.0	109
25	625.0	70

After determining plant densities, the layout of plants across a site must be decided. The simplest approach is to distribute plants uniformly across appropriate hydrologic planting zones, evenly distributing different species at a specified spacing. This will result in uniform coverage and easy installation and monitoring (especially several years later after vegetation gets thicker).

Hydrologic planting zones are described by mapping the frequency of inundation on the planting surface. Typical zones are:

- summer low water level to limit of perennial vegetation
- limit of perennial vegetation to 2-year return flood elevation
- 2-year to 10-year return flood elevation
- 10-year to 25 year return flood elevation
- above 25 year return flood elevation.

Plants have specific inundation preferences. Creation of flood inundation maps, for larger projects, assists in determining appropriate placement. Refer to **Riparian Restoration and Management Figure 1**.



Riparian Restoration and Management Figure 1: Hydrology-based planting zones.

Planting by hydraulic zone alone does not necessarily optimize fish and wildlife habitat and aesthetics. One should also base the planting layout on the size and type of material, the individual plant species habits, and the habitat needs of fish and wildlife. For example, low-growing shrubs or herbaceous plantings might be distributed uniformly across a streambank, while tall shrubs and trees are clustered near pools to provide fish cover. When planting a number of species in the same area, group similar plants together in clusters rather than interspersing all species equally. This will mimic natural plant distributions, making it more aesthetically pleasing. Plants that tend to form thickets, such as salmonberry (*Rubus spectabilis*) or hardhack (*Spirea douglasii*), should be planted close together. Plants that tend to grow as solitary individuals, such as many tree species, should be planted further apart.

When planting the riparian zone above the top of the bank, future maintenance requirements should also be considered. Grasses and weeds surrounding new plants often need to be mown or otherwise suppressed for three years or more to minimize competition until the plants are firmly established. New plants often need supplemental water during the first year (and sometimes through the second summer) following planting. Maintenance will likely be easier if plants are spaced far enough apart to allow a mower to operate between them, or if plants are grown in distinct clusters or bands. Clustered planting offers the advantages of making the plants easier to find, and of limiting the area requiring weed-whackers or other hand-held tools to within and immediately outside of the cluster or band. Mowers or tractors can be used between plant clusters, if necessary. Heavy mulch between plants within the cluster or band will suppress weeds and conserve moisture so as to minimize the necessary frequency of maintenance. However, mulch is not generally recommended in areas subject to frequent flooding. Cluster planting may also offer an acceptable compromise for landowners unwilling to sacrifice their view in order to revegetate the riparian zone. Maintenance issues are of less concern on the streambank because the desired uniform coverage will likely happen if the newly planted vegetation is left alone.

5.4.5 Timing of Plantings

Each plant material type has an optimal planting window, summarized in **Riparian Restoration and Management Table 4**. In riparian areas, timing of flood flows or wet site conditions might prevent or limit site access during otherwise acceptable planting periods. Suitable planting periods for each plant material type must be considered and adequately incorporated into project implementation and construction planning.

Riparian Restoration and Management Table 4. Recommended Planting Window

Plant-Material Type	Recommended Planting Period
Seeding	Spring/fall is best; summer seeding needs irrigation
Dormant cuttings	Spring/fall is best; possibly winter
Containerized/rooted plantings	Spring/fall is best; summer plantings need irrigation
Bare-root plantings	Late winter/early spring only
Salvaged trees/shrubs	All year where the ground isn’t frozen, but dormant season (November to March) is best; irrigate and prune summer transplants
Salvaged sod	All year where the ground isn’t frozen and soils remain sufficiently moist; irrigate summer/fall transplants
Ball and burlap trees	Spring/fall is best

Note that the Washington Department of Transportation’s (WSDOT) standard planting window for non-irrigated material is September 15 to March 31, although a more realistic time frame would be between mid October and mid March. WSDOT allows irrigated plant material to be installed throughout the growing season provided that the irrigation system is operational prior to installation.

5.4.6 Site Preparation

Site preparation is conducted prior to installation of plant materials. Because of the natural fluvial processes that occur in streambank and riparian areas, some site-preparation strategies used in upland forests, grasslands and landscaped areas may be inappropriate. For instance, techniques used to control competing vegetation in uplands, such as weed mats and mulch, although often beneficial in areas with low short-term risk of flooding, may be washed away if used in frequently flooded areas such as streambanks. There is often a trade-off in both cost and effort between aggressive site preparation and required site maintenance. For instance, the required maintenance at a site dominated by dense thickets of weeds may be lower if aggressive site preparation techniques are employed. As a result, the magnitude, longevity, and periodicity of available funds should be considered when selecting site preparation techniques.

When developing a planting plan, consider the necessary site preparation and short- and long-term maintenance, as well as the equipment required. If a site will require aggressive site preparation or frequent mowing to control the growth of undesirable vegetation, and funding is limited, it may be more cost effective to plant dense clusters of vegetation, employing aggressive site preparation techniques within each cluster, rather than uniformly distributing vegetation throughout the site. This will reduce the preparation and planting area and allow the use of a mower or tractor between clusters rather than requiring use of a weed-whacker throughout the entire site. These planted areas can then be expanded as more funding becomes available.

5.4.6.1 <u>Soil Amendments</u>

Soil fertilizer that is regularly applied in uplands may not be appropriate in riparian zones for several reasons. Many riparian species naturally thrive in relatively sterile soil, characterized by high sand and gravel/cobble content and may already be adapted to low-nutrient sites or obtain their nutrients in association with stream flow. In addition, surface applications of fertilizer may be washed away by flood flows and contribute excess nutrients to the aquatic system before riparian plants can utilize them. Weeds may also be more competitive on fertilized sites than on typical alluvial sites that are dominated by low-nutrient, sandy and gravelly soils.

If soil amendments or supplements such as compost, topsoil or fertilizer are to be used, they should be organic products with slow-release characteristics, and they should not be applied to the surface of the soil. Rather, they should be mixed into the rooting zone with existing soils. Amending existing soils and physically incorporating these amendments into the rooting zone increases their retention under flood flows and may encourage deeper rooting than if amendments are placed on the soil surface.

An amendment that may be worth considering in droughty sites, at least on an experimental basis is a product referred to as “water crystals.” Water crystals are synthetic polymers added to the rooting zone that can improve moisture retention and thereby allow plants to better withstand drought. Although some studies have not found this amendment to provide conclusive benefits[13], variation in application rates and techniques may be worth investigation[19].

5.4.6.2 <u>Topsoil Salvage and Irrigation</u>

If excavation is occurring on site, separate topsoil from sub-soil during excavation and stockpile for later use. Following excavation, the native topsoil can be reapplied to the new surface prior to planting. If restoration activities include use of a temporary irrigation system, the irrigation system should be operational prior to plant installation.

5.4.6.3 Soil Scarification

On sites with heavily compacted soils or large patches of invasive weeds, soil scarification may be required to promote plant rooting, growth, soil drainage, and reduce competition. Common techniques include disking, scalping, bedding and plowing. All aim to change or construct different physical properties that may influence seed germination and seedling establishment and survival. Be aware however, that if flood prone soils are scarified excessively they may be more susceptible to erosion. Site preparation techniques to control undesired vegetation are discussed below under *Weed Control*.

5.4.7 Weed Control

Weed control and monitoring will be an essential component of any riparian restoration project, particularly during the early plant establishment phase. Invasive non-native plants can doom a revegetation effort as they compete for light, moisture, and space (both aboveground and below). This can be especially true where aggressive species such as reed canary grass or blackberry dominate an area. Aggressive continued control is necessary until new desirable riparian vegetation is firmly established.

Riparian areas dominated by invasive non-native plants are often targets for restoration because they often affect the structure and development of native plant communities. Since restoring the optimal native plant community at these sites may be difficult or impossible given the competition, a native substitute community capable of surviving and suppressing weed growth in the long term may be the best option. The only long-term method of weed control is to create conditions unfavorable for weed propagation, establishment, and survival or else eradicate or minimize the seed source. Unfavorable site conditions may include shading of sun-loving weed species or periodic flooding of flood intolerant species. For instance, encouraging the establishment of native conifers may suppress weeds in time as canopy closure reduces light penetration to the understory and reduces the number and extent of non-native plants[5].

Weed removal over a large area may, temporarily, decrease bank and floodplain stability due to reduced vegetative cover. For instance, tilling removes all vegetative cover and exposes bare soil to erosion. This reduced cover may also reduce the quantity or quality of wildlife habitat until native vegetation is established. The short-term impact of weed removal on soil stability and fish and wildlife depends on the technique employed. Nevertheless, suppression or successful eradication of weeds often provides significant long-term benefits.

The method of weed control should be carefully selected, its benefits weighed against potential negative impacts. For instance, removal of reed canary grass from a stream channel may increase channel conveyance of water, sediment, and woody material and allow a diverse channel bedform and plant community to develop. However, if dredging is used to remove reed canary grass from the channel, the physical and biological effects include direct destruction of instream habitat and aquatic life within the area of application and destabilization of the upstream channel. It may also alter the cross-section and profile of the stream causing channel incision or aggradation, and isolating the stream from its floodplain, which in turn impacts plants and wildlife within the floodplain. These effects may extend up- and down-stream of the dredged area.

Before implementing weed control, a thorough understanding of the following considerations is recommended:

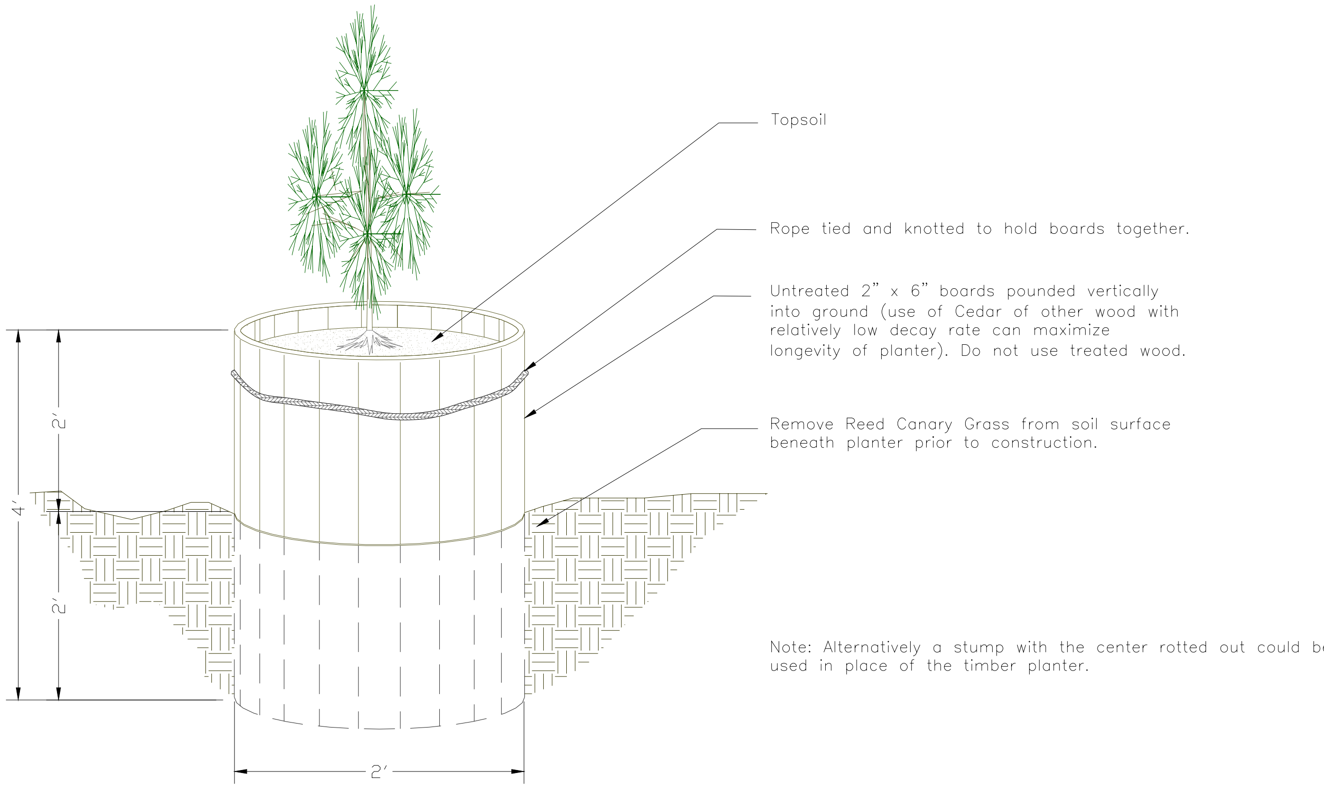
- Biology of the targeted species;
- Short- and long-term effectiveness and limitations of control efforts;
- Risk to non-target species and the ecosystem as a whole; and
- Long- and short-term availability of funds and work crews.

While the only long-term methods of weed control are to eliminate it seed source and to create conditions unfavorable for weed propagation, establishment and survival, a variety of techniques can be used to temporarily control and manage weeds including:

- Manual and mechanical control
  - Pulling by hand or with tools such as a Root Talon or Weed Wrench, girdling, mulching, mowing, tilling, plowing, surface soil scalping or disking, dredging, singeing with hand held torches, flooding, and solarization,
- Controlled grazing with cattle, sheep, goats, and even geese
  - Controlled grazing consists of short duration (i.e., less than 1 week) high intensity grazing during vulnerable life history stages of the target species.
- Mulch and/or weed barrier fabric
- Prescribed fire,
- Flooding,
- Biological control, and
- Controlled herbicide applications at appropriate times of year[20].

These techniques often work best when used in combination (i.e. mowing followed by disking, or removal of weeds by hand followed later by controlled herbicide application). Some of these techniques will be required to prepare the site, prior to planting; while others will be required as part of a short- and long-term maintenance plan. Often, there is somewhat of a trade-off between pre-project site preparation and post-project maintenance. For instance, on upper floodplain sites that have a low probability of flooding (and subsequent soil erosion), weeds throughout the site can be killed with herbicide or knocked back by mowing immediately prior to planting. Following this up with the application of a biodegradable weed barrier such as cardboard covered with a thick layer of mulch immediately after planting can suppress weed growth and retain soil moisture, minimizing the need for long-term maintenance. Alternatively, weeds may be initially removed only around the immediate vicinity of each new plant; frequent mowing around each plant will be necessary to suppress weed growth and minimize plant competition. Consult your state or local weed control board, conservation district, or Washington State University Cooperative Extension office for specific information and recommendations to control common weeds found in Washington. The Nature Conservancy has a very comprehensive "how to" manual for a variety of weed control techniques[16], another reference is by Leigh[21], both are available online (websites are provided in references). A common riparian weed in Eastern Washington that can be very difficult to remove is Russian olive. The NRCS has an excellent pamphlet on techniques to remove this specie[22]. No matter what the weed or strategy employed, weed removal efforts will likely be short-term if not combined with revegetation efforts to crowd, shade out, or otherwise suppress the weeds.

One experimental method of reed canary grass control that may not be found in references is the creation of artificial hummocks or planting mounds in the surrounding riparian zone using heavy equipment. Various versions of this concept have been employed in western Washington. One version, employed by the Skagit Fisheries Enhancement Group and the Jefferson County Conservation District, consists of creating mounds of earth 2 to 5 feet tall of various size and shape throughout the riparian zone and planting them with native vegetation. Another version used by King County included installing untreated wooden planks vertically into the ground to form a round planter 2 to 3 feet above the surrounding soil (see **Riparian Restoration and Management Figure 2**). The planter was then filled with soil and planted with Sitka spruce, which was abundant on natural hummocks in the adjacent wetland. These hummocks or mounds create relatively dry microhabitats that may offer vegetation planted on them a competitive advantage over the surrounding stands of reed canary grass. Preliminary monitoring data for the earthen mounds found that plant survival was higher and reed canary grass was less dense on the mounds versus off the mounds[9]. Further study is necessary to determine the long-term effectiveness of this technique and the hydrologic and hydraulic impact of the mounds. A variation of this approach would be to use the heavy equipment to scalp a large portion of a reed canary grass monoculture to remove much of the rhizomes and stems while also creating the hummocks.



Riparian Restoration and Management Figure 2. Example of artificial planting hummock.

5.4.8 Planting Techniques

Proper storage and planting is critical to the success of stream revegetation projects. All plants used on site should have a healthy, vigorous appearance, free of dead wood and disease. Properly store plants prior to planting by protecting them from sun, wind and physical abuse. The appropriate planting technique in streambank settings depends on the type of plant material. If planting in an area that's heavily vegetated, such as a pasture or meadow, remove vegetation from at least a three-foot-diameter circle where the new plant will be set to minimize competition for light, water, and space. All plants should be watered immediately after planting to eliminate air pockets and to ensure that moisture around the root ball is at or near field capacity.

5.4.8.1 Seeding

Developing Seed Mixes. Seed mixes are combinations of grass, forb and occasionally woody plant seeds, intended to provide both short- and/or long-term cover, depending upon the specific project. Some suggestions follow:

- More species are not necessarily better. Select three to five species with a range of seed sizes that are biologically suited to your site.
- Do not specify hard-to-find or unavailable species unless you intend to collect them yourself and have them contract grown to supply sufficient seed the next year.
- To the extent possible, use locally collected seed.
- When purchasing seed, select seed certified weed free and inspected by the Washington State

Department of Agriculture.

- Seeds should be delivered to the site in the original, unopened bags showing a certified net weight, date of germination tests, supplier's name, certified guarantee of analysis including the composition, purity and germination percentages, and percent weed seed. Seed should not contain more than 1% weed seed with 0% desirable. No noxious weeds should be specified and listed on the label. For areas east of the Cascades, the seed mix should specify no sweet clover.
- Select at least one proven, quick-establishing species. This may justify use of short-lived non-native cover crops, such as annual rye or winter wheat. Or try a sterile hybrid such as Regreen® or a native, dry-site species, such as slender wheat grass or Canada wildrye, that provides good short-term erosion protection but will eventually be replaced by a species more tolerant of moist soils. Short-lived species are particularly appropriate when vegetation established by seed is expected to provide only short-term erosion control until native herbaceous and woody plants get established. Short-lived species will provide less long-term competition. On surfaces that are considered droughty, the use of annual cover species may result in poor establishment of perennial species. Annual species may consume soil moisture early in the establishment period stressing slower establishing perennials. The result is that perennial species may take longer to establish or need several seedlings to compete effectively with annuals.
- More seed is not necessarily better. Instead, focus on getting good seed-to-soil contact by firmly compacting seeded streambank areas with excavator tracks, an excavator bucket or a contractor's compacter. Imprints left in the soil by tracked equipment during construction can help to collect seed and rainwater and provide a moist microclimate for seed germination.
- Have a seed supplier help determine seed rate, and purchase seed in pounds of Pure Live Seed (also referred to as "PLS lbs.").
- Experiment with different species, and monitor results.
- After applying a simple seed mix containing three to five species, add diversity by separately seeding a wildflower mix in scattered locations across the seeded area. Use caution when buying wildflower seed mixes. Make sure all species are listed and all are native to the project area.

To maximize survival, seed should be planted during the correct planting season as recommended by the seed supplier. To provide erosion control during the winter months, seed must sprout and root well prior to the start of the winter dormant season. Straw mulch can increase the likelihood and rate of seed germination, even if the straw later washes downstream. Where the potential for natural recruitment of native vegetation is high, lightly seeding the area may be more effective than heavily seeding. This will limit competition for the native vegetation.

Erosion-control fabrics can be used in conjunction with or in place of straw mulch to prevent straw and seed from washing downstream. It is recommended that only fabric comprised entirely of natural material be used. Fabrics that uses a plastic netting or mesh can easily get blown or washed into the adjacent stream or watercourse and act as a gillnet for fish. It may also be harmful to wildlife that ingest or become entangled in it. Generally, plastic netting also has a long life and may not be aesthetically appropriate. If using plastic bound mulch, select a variety that decays quickly. Clear plastic covering can be useful to prevent erosion of seed (and mulch if applied) from fall rains and enhance establishment with the “greenhouse effect” but should be removed once growth is underway. If growth is not monitored and the plastic removed when appropriate, the new growth will become overheated and smothered.

Preferred Seeding Methods.

There are three primary seeding methods: drilling, broadcasting and hydroseeding (see **Riparian Restoration and Management Table 5**). The most appropriate method for a particular site will depend on terrain, accessibility, soil characteristics and time of seeding. The preferred and most effective method is drill seeding. However, if the site is on uneven ground containing obstacles or debris, or is inaccessible to large equipment, broadcast seeding is preferable. Hydroseeding is a less effective method because if water levels rise above the seeded area before germination and seedling establishment, the mulch, binder, and seed will float and wash away. It should, therefore, be limited to steep, inaccessible areas. Prior to seeding an area, consider risks from wind displacement or rising water levels, which can displace and wash away seed/seedlings, mulch and binders, particularly when using hydroseed.

Riparian Restoration and Management Table 5: Advantages and Disadvantages of Various Seeding Methods.

	Advantages	Disadvantages
Drill Seeding	Proven high revegetation rate	Cannot be used on rocky soils or steep slopes
	Most successful on slopes 3:1 or flatter	Unless specially modified drills are used, all seeds, regardless of size will be planted at the same depth; the smallest seeds are likely to be planted too deep
	Seed depths and seeding rates can be closely controlled	Seeds drilled in rows may suffer from high inter-seedling competition
	Seed to soil contact is high, maximizing germination	Leaves rows, which often persist for many years, which may be visually unacceptable.
Broadcast seeding	Can be used on slopes that are steep, rocky, remote or inaccessible	Germination and establishment tends to be lower
	The variable planting depths that result from broadcast seeding allows better establishment of small seeds lower seed to soil contact without some kind of packing or dragging	Requires double or triple the seeding rate of drill seeding and seeding rate calibration is less precise.
	Vegetation not in rows	
Hydroseeding	Can be used on slopes that are steep, rocky, remote or inaccessible	Results less satisfactory due to poor seed/soil contact; fewer seeds germinate
	Vegetation not in rows	Dependent on local water supply

Tips for drill seeding:

- Seed to a depth of 0.25 to 0.5 inches. This is dependent on the size of the seed (based on grass species). Larger seeds should be planted ¾ inch deep.
- Seed along the contour to avoid erosion from water flowing down drill furrows

Tips for broadcast seeding:

- Before seeding rake or harrow soil to eliminate crusting
- After seeding cover the seed by harrowing, chaining, or raking
- Do not seed on windy days

Tips for hydroseeding:

- Do not mix seed and mulch together in a single slurry
- Do not use hydroseed containing fertilizer
- Spraying hydroseed slurry on steep, impermeable slopes may wash seeds off the slope.
- Hydroseeding often results in sheets of mulch and seed, which can be damaged or lost in overbank flooding events that occur before seeds germinate and take root.

5.4.8.2 Collection, Harvest and Installation of Cuttings

Live cuttings are the most common type of plant material used on streambanks. There are many on-line and published planting guidelines, but some additional tips related to collection, storage and installation are described below:

- Best survival occurs with dormant collection and planting, but anecdotal reports suggest that successful establishment is sometimes possible from cuttings planted in early summer and early fall, especially if leaves and branches are stripped from the plants and cuttings extend into moist soil or are irrigated, but the success rate is rarely more than 40%.
- Collect cuttings from healthy vigorous stock; those collected from stressed plants root poorly. Collect cuttings from male and female plants, if applicable. One- or two-year-old wood is generally better than older wood, and cuttings taken from the center and bottom of the plant will frequently root better than those taken from the outside edges. A general rule of thumb is to take no more than 1/20 of an individual plant[7]. When harvesting cuttings, don't clear-cut the source area.
- Cuttings should be at least one half inch in diameter, relatively straight, 12 to 48 inches long, and include two or more nodes (buds). One (or more) node is for the roots of the new plant and one (or more) is for the leaves. Some plants have very long sections between nodes so your cuttings may need to be longer than 18 inches. Longer cuttings may also be necessary depending upon planting site conditions (e.g., deep water table; erosive forces) and application (e.g., brush layers and fascines versus live stakes). Generally, cuttings should be long enough to extend into the moist soils in the vicinity of the lowest seasonal water table with no less than ½ of the total length of the cutting in the ground[23]. Experiment with a variety of cutting diameters, since literature on the most successful stem diameter is not consistent and varies depending upon species under consideration[7]. Cutting diameters less than one half inch may be necessary for species with relatively small diameter stems (e.g., *Spirea* spp.).
- Harvest cuttings with a clean, diagonal cut, and make sure the base of each cutting is inserted into the ground. Cutting the bottom with angled cut and the top with a straight cut and dipping the tops in latex paint will help identify the top from bottom. Upside-down cuttings become established much slower if at all!
- Cuttings should be kept moist, relatively cool, and shaded until planting. Even on a cold day, exposure to direct sunlight will stress them. Soak cuttings (at least that portion of the cutting that will be underground) in water for 24 hours to 10 days (soaking longer than about 14 days for most species will allow the root tips to emerge from the bark. This will cause problems when planting because they are easy to break off) prior to planting to improve survival. This is also an excellent, temporary, on-site storage method. Water should be changed daily. Cuttings will be most successful if harvested and planted in the same day.
- If cuttings cannot be installed within days of collection, consider long-term storage (up to several months) under cool, damp (not wet. Don't cover with wet burlap or wet shredded newspaper, store dry and hydrate by soaking), dark conditions (refrigeration).

- Never plant cuttings into dry soils.
- If the site is not irrigated, the bottom of the cutting must reach a depth where the soil is permanently damp. The literature is not conclusive on what percentage of the cutting should extend above ground. One quarter is often recommended (especially for arid areas), no more than one half, but experiment with variations and monitor results. If more than one half of the cutting extends above the ground, there will likely be too much shoot growth for the short sprouting roots to support. The plant will become quickly desiccated and die. When planted, at least one node should be buried and one node left exposed to establish roots and shoots, respectively.
- When planting cuttings in relatively loose, friable soil (i.e. sandy loam), tamp them in using a “dead blow hammer” (i.e., a hammer with a head filled with shot or sand)[24]. However, driving cuttings into hard or rocky coarse soils in this manner tends to peel back the bark and they have a reduced chance for survival. Instead, use rebar, an iron bar, or similar tools to develop a pilot hole for the cutting. The diameter of the pilot hole should be slightly smaller than the cutting to ensure good stem-to-soil contact. The live stem must fit tightly in the planting hole, leaving no air space.
- Consider planting dense willow “rows” (3-5 per lineal ft) in an excavator-made trench, rather than “hand” planting individual cuttings. Cuttings should be 5-10 ft in height; the trench should be at least half the length of the cuttings; and reach the water table. Such willow rows are inexpensive, do not require irrigation, resist pullout during flood events, and create floodplain roughness.

Refer to the *Construction Considerations* section of this technique for more information on specialized planting tools and techniques.

5.4.8.3 Installing Containerized Plant Materials.

The success of planting techniques for containerized plants depends in large part upon the specific container size and dimension, making generalizations difficult. For example, narrow “tubeling” containers can be planted through erosion-control fabric with minimal fabric cutting, but larger containers require cutting fabric strands that can potentially weaken the fabric. On particularly erosive sites where erosion control fabric is employed, the advantages of larger material should be weighed against the potential for compromising fabric strength and integrity.

Depending upon the situation, planting holes can be hand dug with shovels and dibble bars, or with a variety of mechanical equipment including augers, excavators and backhoes, or a tree-planting machine. The planting hole should be roughly twice the diameter of the container. Loosen and uncoil or slice circling or twisted roots to encourage root growth outside of the potting soil. All container plants need to have the top of the soil/root mass planted flush with or slightly higher than the soil surface, and have a suitable backfill material firmly compacted around the root mass. A trough or low soil berm around the planting hole may be used to retain water. However, care should be taken to keep the trunk base dry. Irrigation is recommended in many cases, but is generally not required for dormant-season plantings – plants are adapted to growing following dormant season when soil moisture is either high due to winter rain or snowmelt, or from spring rain and wicking from the stream channel during spring or summer high flows. If using mulch, avoid letting the mulch come in contact with the stem.

Mechanized planting machines should be considered to facilitate large-scale revegetation efforts and those occurring in rocky soil. Refer to the *Construction Considerations* section of this technique for more information.

5.4.8.4 Planting Bare-Root Materials.

Bare-root plants must be planted during the later winter/early spring dormant season. If irrigation is available, the planting season may extend into late spring and possibly early summer, but survival will be extremely low if the buds have broken or begun to open. Roots should be fresh and plump, not dry and withered. Store bare-root plants in a cool, shaded environment with roots covered by moist (but not soggy) mulch or sawdust and not exposed to air. Most nurseries sell bare-root shrubs packed in a silica gel and stored in a special bag with an evaporation barrier, which helps prevent desiccation. In theses cases, the bare-root plants should not be placed in sawdust but kept in their original container. Roots must be kept moist and protected from sun and wind exposure at all times. Installation requires attention to detail to make sure that all roots are directed downward so that none bend up towards the surface, and to make sure that the soil is firmed tightly around the roots so that there are no air pockets. A planting bar can be used to create a slit in the soil that the roots are placed into; the slit is then closed using the planting bar. Roots must be cut to the length of the planting bar to prevent bending the roots at the bottom of the slit. Bending the roots, or "J-rooting" will kill the plant.

If circumstances dictate, create a trough or low soil berm around the planting hole to encourage retention of water. However, care should be taken to keep the trunk base dry. Irrigation is recommended during the first, and sometimes second, growing season following planting, but may not be needed if seasonal, natural precipitation or moist soil conditions are anticipated. If using mulch, avoid letting the mulch come in contact with the stem. As in the case of large, containerized plants, bare-root trees and shrubs planted through erosion-control fabric require fabric strands be cut, thereby weakening the fabric. For this reason, on particularly erosive sites, the advantages of bare-root stock over cuttings should be weighed against the potential for compromising fabric strength and integrity.

5.4.8.5 Planting Salvaged Materials.

Heavy equipment such as a backhoe, excavator or tree spade is advised. While storage and/or transport of salvaged materials are possible, the increased handling, especially for woody materials, tends to increase cost and reduce survival rates. The following sequence is recommended:

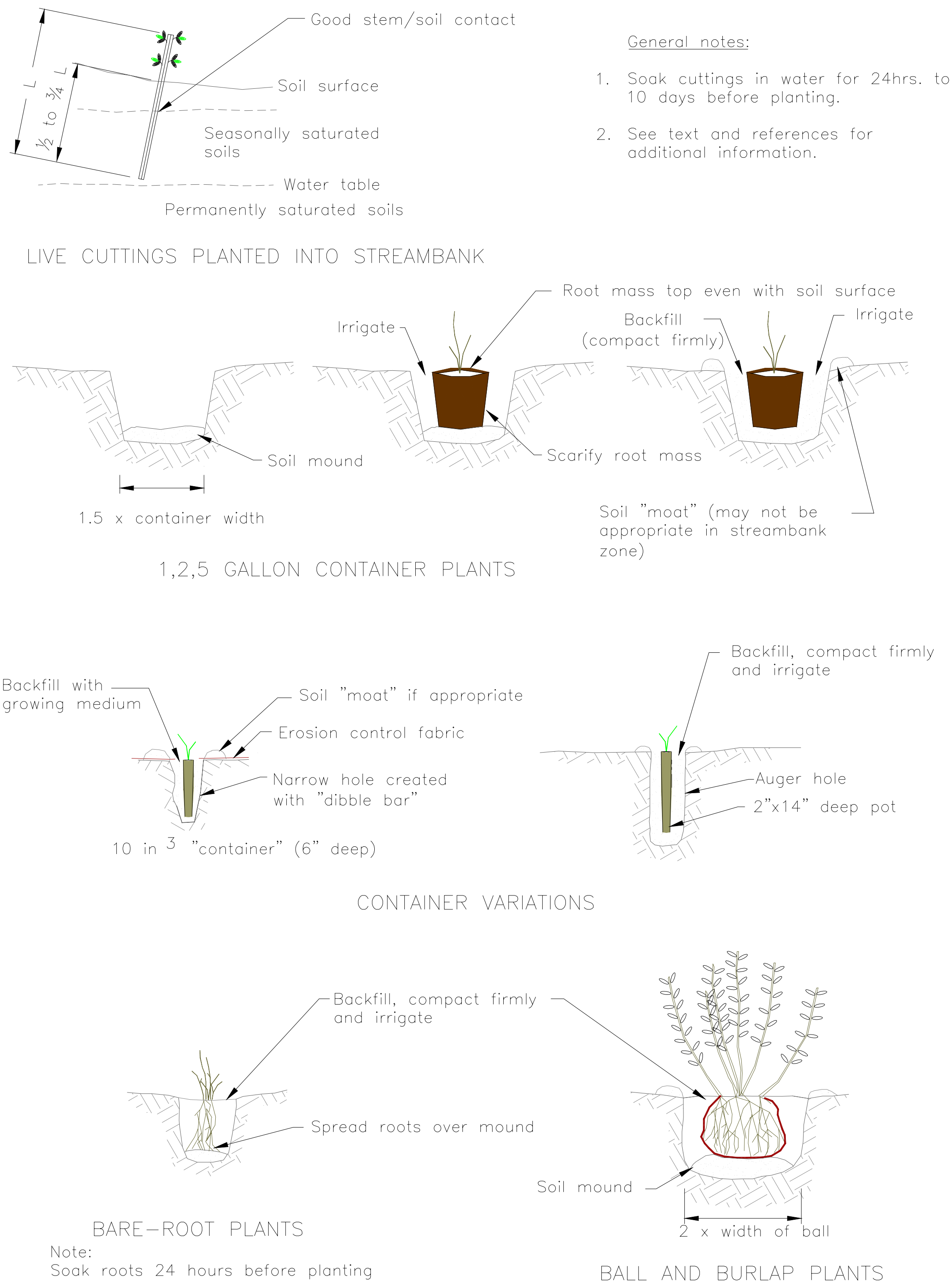
- Prepare the planting site (including digging holes if needed);
- Salvage plants, by excavating as much of the root mass as possible and directly transferring the salvaged plant to the planting site with the soil and root mass intact; and
- Install the salvaged plants in moist soil immediately.

Minimizing transport of salvaged materials is key to their success and survival. Make sure the roots stay damp; they will dry out in seconds if exposed. If the plants must be stored before replanting, they should be handled as ball-and-burlap plants. Transfer the plant from the ground with the dirt around its roots still intact onto a strip of burlap placed alongside the plant. Tie the burlap around the root ball with twine, keeping the dirt intact. To properly store the newly created ball-and-burlap plants, cover the root mass with moist mulch or sawdust. Following planting, irrigation is always advised, and pruning of woody stems and branches will help reduce drought stress[7]. Again, if they will be out of the ground for a while, use the terra-sorb to coat the roots.

Dormant-season salvage is best (November through March) although this is often not possible in eastern Washington due to frozen ground, but if irrigation is available and the risk of somewhat lower survival is acceptable, salvage can take place even in dry or hot seasons. Salvaging plants is most successful if plants are collected from moist soil conditions and planted on wet, cloudy days so that roots are less likely to dry out and soil is retained around the roots.

5.4.8.6 Installing Ball-and-Burlap Plants.

The success of planting techniques for ball-and-burlap plants depends in large part upon the dimensions of the soil ball, making generalizations difficult. Depending upon the situation, planting holes can be hand dug with shovels and dibble bars, or with a variety of mechanical equipment including augers, excavators and backhoes. The planting hole should be roughly twice the diameter of the soil ball. The burlap surrounding the upper one-third of the ball must be peeled back and removed. All ball-and-burlap plants need to have the top of the soil/root mass planted flush with or slightly higher than the soil surface, and have a suitable backfill of native material firmly compacted around the root mass. A trough or low soil berm around the planting hole may be used to retain water. However, care should be taken to keep the trunk base dry. Irrigation is recommended in many cases, but is generally not required for dormant-season plantings is surrounding soil moisture is sufficient. If using mulch, avoid letting the mulch come in contact with the stem. Nurseries that supply these types of trees and shrubs can provide excellent planting guidelines. Remember, the large size of the planting hole and the potential for guy wires to collect flood debris limit the application of this plant material type on streambanks. These planting requirements may be less of a concern on floodplains.



Riparian Restoration and Management Figure 3: Conceptual drawings of plant installation.

6 PERMITTING

Any construction activities in wetlands associated with placement of fill (e.g., creation of hummocks in a reed canary grass stand) or instream work is subject to federal, state, and local permitting including Section 404 of the Clean Water Act, Washington State Hydraulic Project Approval, and potentially Endangered Species Act (ESA) and Shoreline Management Act approval. Development of alternative water sources may require a water right from Department of Ecology as well as ESA consultation if there are listed fish in the stream from which water is drawn. Herbicide application may also require the use of licensed applicators and ESA consultation if there are listed species that could be affected. The type of herbicide employed around water and the timing and method of application is also restricted. Contact the Washington Department of Ecology or the Washington Department of Agriculture for information regarding herbicide use in and around open bodies of water. Refer to the *Typical Permits Required for Work in and Around Water* appendix for more information regarding each of these and other permits that may apply.

7 CONSTRUCTION CONSIDERATIONS

Access routes, project timing, and type of equipment used should be selected to limit the impacts of heavy equipment on streambanks, floodplains, wet soils and stream channels. The risk of exposing equipment to flood events should also be minimized. See the *Construction Considerations* appendix for more details

7.1 Equipment

The project's scope and site conditions will determine the types of tools required for the installation of riparian vegetation. Where soils are fine-textured, moist and not overly compacted, plants can be effectively installed with hand tools. Often, however, it is more effective to use some type of mechanized planters to create planting holes, especially if long cuttings are being installed or if soil is coarse-textured or over-compacted. Conventional earthwork equipment, such as bobcats, backhoes, augers, excavators and tree spades can be useful for installing riparian vegetation. Additionally, restoration practitioners have developed planting devices specifically for woody plantings. Some examples include the stinger, which is used for interplanting riprap; the ripper, which is used to plant cemented floodplain soils; and the water-jet stinger[25 26] which uses pressurized water to create a deep hole for planting long willows in fine textured soils. With the exception of the stinger, all of these devices were developed exclusively for planting cuttings. A variation of the stinger was developed that is capable of planting three-inch-diameter rooted-plant plugs. These tools are described briefly below.

7.1.1 Stinger Method

The stinger method makes it easier to plant cuttings in compacted streambank soils and riprap revetments. As an attachment to a backhoe or excavator, the stinger can push three to four inch-diameter cuttings into the soil to depths of up to approximately seven feet[23 27]. The Janicki stinger was developed in 1995 for the Washington Department of Fish and Wildlife to attach to the bucket of an excavator. It consists of a solid steel rod, approximately three to four inches in diameter, that creates a pilot hole through coarse or rocky layers of streambank or riprap and stops when it reaches the softer, native soil underneath (subsoil). The finer subsoil serves as a rooting zone for installed willow or cottonwood pole cuttings. Cuttings are inserted into the pilot holes by hand and pushed down to the required depth with the heel of the bucket. Care is required to ensure that cuttings are footed in moist subsoil and that there is a continuous tight fit between the cutting and the soil. The cutting should make its own hole through the native subsoil. No more than one-half of each cutting should protrude above the soil; six inches is recommended. This system has been used across western Washington with great success and eases planting in difficult conditions such as floodplains where water tables are as much as six feet beneath the ground surface or in streambanks with riprap layers up to five feet thick. The Janicki stinger can plant 40 to 50 cuttings per hour on average. Because the Janicki stinger can push the cuttings in only as far as the riprap surface, cutting survival may be low in thick layers of riprap, unless soil has been incorporated into the riprap matrix.

A planting device similar in purpose to the Janicki stinger is the “expandable stinger,” which consists of a pair of eight-foot-long, elongated probes, with an internal plant receptacle (**Riparian Restoration and Management Figure 4**). This device was developed and patented by Dan Culley of Dayton Tractor in Dayton, Washington and is now available from Northwest Revegetation and Ecological Restoration (erniek@nwrer.com). The bottom tips of the probes can be closed to hold the plant within the plant receptacle and opened to release the plant into the ground. Like the Janicki stinger, the expandable stinger also attaches to an excavator bucket. The cutting is placed inside the probe’s plant receptacle, and the excavator drives the probe into the ground. Once the probe has reached the proper depth in the soil or riprap, the operator opens the probe (it operates hydraulically from the cab of the excavator), and the cutting is released. The probe is then removed from the hole; the probes are closed; a new cutting is inserted, and the process is repeated. The advantages of the expandable stinger over the Janicki stinger include:

- The cutting is protected at all times (leading to potentially higher survival rates) rather than being pounded into place.
- Smaller-diameter cuttings can be used. The probe can accommodate 1/2-inch- to four-inch diameter cuttings that are up to four feet in length. Larger cuttings may be held in the tip of the probe and driven into the soil.
- The “shear wall,” a compacted wall in the planting hole created when planting tools are inserted into the soil, is minimized or eliminated. The probe tip of the expandable stinger has longitudinal ribs that break up the compacted soil around the walls of the planting hole as the probe is removed and allows the now-loosened soil to fill the hole. Without this feature, shear walls can be created, hampering the proper dispersal of roots and often resulting in poor or unsuccessful growth.
- Field crews remain relatively safe on the top of the bank rather than having to climb along the banks in close proximity to heavy equipment operation.

The expandable stinger is capable of planting in streambanks, floodplains and through riprap up to four feet thick. It has been used to plant 30 to 250 cuttings per hour, depending upon site conditions.

A variation on the expandable stinger, also available from Northwest Revegetation and Ecological Restoration, is capable of planting three-inch-diameter rooted-plant plugs into unarmored streambanks at a rate of up to three hundred per hour (see **Riparian Restoration and Management Figure 5**).

Riparian Restoration and Management Figure 4: Expandable stinger for live stakes and 3" plugs. It has been used to plant 30 to 250 cuttings per hour, depending upon site conditions.

Riparian Restoration and Management Figure 5: Expandable stinger variation capable of planting 3"-diameter rooted-plant plugs into unarmored streambanks at a rate of up to three hundred per hour.

7.1.2 Ripper Method

The ripper was also developed to facilitate revegetation efforts in cemented floodplain soils with deep water tables. It consists of a five-foot-long shank pulled behind a D-8 Caterpillar bulldozer or equivalent. The shank creates a narrow trench in the soil. Up to four workers drop cuttings into the trench from a platform on the tool bar of the ripper as it moves along. The ground may collapse under its own weight back onto the cuttings. More often, however, to ensure good soil contact with the cuttings, the operator must ride over soil mounded up to one side of the trench with the outside of the bulldozer track. The minimum width between trenches is the width of the bulldozer track, approximately four to five feet. Trenches are normally placed perpendicular to the stream or at a downstream angle. Advantages of the ripper include that it loosens the soil around the cutting to promote good root development, and the trenches of relatively uncompacted material can help to draw water from the stream to recharge the aquifer. Disadvantages include that it can only be used on large-scale projects, and the ground is left in a roughened state that may not be acceptable if immediate aesthetics are of concern or if disturbed soils are at increased risk of erosion. The ripper has been used to plant an average of 1,000 cuttings (up to six inches in diameter) per hour into cemented floodplain soils.

7.1.3 Water Jet Stinger Method

Another method to create a deep, narrow hole for long willow or cottonwood pole cuttings is the water jet method[28,22]. Unlike the stinger, this method is designed for sites with fine-textured soils, a low rock or gravel content, and relatively deep water tables. This planting system consists of a gasoline powered water pump that forces water from the nearby stream through a long rod with a special nozzle. The nozzle creates a pressurized flow capable of creating a six-foot-deep hole in approximately 20 seconds (in good conditions). The length of rod depends on the length necessary to reach the summer water table, but typically ranges from 3 to 10 feet. If the willow cuttings are promptly placed in the scoured holes, the slurry of saturated sediments within the hole will form a tight fit between the cutting and the soil, which increases cutting survival.

7.1.4 Construction Sequencing

Construction sequencing for riparian restoration activities must consider vehicular access as well as material placements to ensure efficient progress. For example, consider the re-vegetation of a floodplain surface dominated by weedy plants. A comprehensive sequence might be as follows:

- Clear and grub surface sod and vegetation temporally, stockpile salvage materials as shown on the plans
- Excavate planting holes for bare-root stock in zone A on as shown on the plans.
- Plant bare root stock and salvage materials in zone A and prepare soil surface for hydromulch
- Hydromulch zone A using access road through zone B as shown on plans
- Disc zone B to ensure soil compaction of haul roads meets specifications
- Place erosion control fabrics and broadcast seed mix per specifications in zone B
- Plant stem cuttings using hand crews in zone B as shown on the plans
- Construct temporary irrigation using hand crews

- Erect site access barriers.

It is important that heavy equipment has access to areas where necessary, but compaction caused by access should be minimized. Similarly, once seed or erosion control fabrics are in place, access by heavy equipment should not be permitted. Vehicular traffic on top of fabrics or seed, or through areas densely planted with stem cuttings should be avoided as damage could occur.

7.2 Contracting Considerations

Use of volunteer work crews can be well suited to riparian restoration projects. If well supervised and trained, volunteer work crews can be a cost-effective means to install fences or plants, and monitor recovery, changes in landuse, or response to flood events on a modest scale. However, on larger jobs the efficiency and expertise of a contracted work crew is generally more cost effective and easier to manage than a volunteer crew.

Contracts with paid work crews should allow for some “fit-in-field” adjustment. This applies especially to planting efforts so adaptive management can respond to unanticipated field conditions such as unexpected soil types, higher flows than expected, changes in plant material availability, or slower construction/installation rates. Revegetation efforts may benefit from installation in phases, or over several planting seasons so that plant species are installed in proper microsites.

Also consider contractor bonding especially on jobs bid with survival specifications. Some jobs are bid so that it is up to the installation contractor to ensure 90% survival of planted vegetation usually a year from the planting date. While percent survival and duration is often negotiated, many contractors may not want to come back and replace materials that died or otherwise failed to meet vegetation specifications. Bonding of the contractor will give the project proponent a sum of money to repair deficiencies if necessary.

8 COST ESTIMATION

Revegetation efforts are sometimes given a low priority in aquatic restoration projects because they are perceived to be expensive or natural regeneratation is inappropriately assumed to be sufficient. Given the potential benefits of native revegetation discussed above, the costs are actually relatively low compared to many stream restoration activities, especially those that require work within the channel. General planning level estimates for reestablishing native vegetation on unvegetated flood prone surfaces typically run between \$0.15 to as high as \$3 dollars a square foot. More detailed costs of individual components are provided below.

Planting costs depend on the scale of the effort, required site preparation, planting technique (machines vs. hired hand labor vs. volunteer hand labor) and long-term maintenance costs. Direct costs include site preparation, plant materials and installation, and long-term maintenance. Indirect costs may include establishment and administration of easements, negotiation of dam water management, and fencing where livestock exclusion is necessary. Additional costs will be incurred if significant channel and floodplain restoration is required to restore a functional riparian hydrologic regime (e.g., if the stream is incised or the floodplain has been filled or levied. In some cases, revegetation costs are cheaper in the long-term, due to reduced maintenance and replanting costs, if extra money is spent initially to purchase larger plant materials, install browse protection or implement an irrigation plan. Use of heavy equipment to create deep trenches to plant high-density willow clumps is often less expensive than spreading more labor-intensive hand-planted individual cuttings uniformly over a broad area.

Some approximate costs for woody plant materials are as follows: Please note that these represent wholesale material costs only and depend on the quantity ordered.

- 3 feet long willow cuttings - $2;
- 6 inch diameter willow post - $25;
- 10 cubic inch shrub tubeling - $0.90 to $2;
- 10 inch herbaceous plug - $0.90 to $1.25
- 1-gallon containerized shrub - $3 - 8;
- Locally salvaged willow clump - $25; (includes labor and equipment to dig, transport and store on site)
- 1 to 2 foot tall bare-root shrub - $.50 - 1.50; and,
- 1.5-inch caliper ball and burlap tree - $100.

Costs for installation depend on equipment costs, site conditions and the scale of job. Labor costs vary depending on the project location. **Riparian Restoration and Management Table 6** provides labor time estimates for various kinds of planting work. These times can vary depending on the physical condition and experience of the planting crews[29].

Riparian Restoration and Management Table 6: Estimated labor time for various types of plant material.

Activity	**Per Person Labor Required**
Dormant posts	10-20 posts/hr
Willow cuttings	45-50 cuttings/hr
Seedling planting	30-120 plants/hr
Ball and burlap shrubs	1-15 plants/hr
Containerized plants	20-100 plants/hr
4 cubic inch plug	120 plants/hr
10 cubic inch plug	90 plants/hr
Seeding	
Broadcast	0.05-0.5 ac/hr
Hydroseeding	0.12-0.37 ac/hr

Approximate installed costs for fencing per linear foot are: $0.90 for 3-5 strand barb wire fencing in rangeland applications; $1.25 for woven wire rangeland fence; $1.15 for 3-5 strand barb wire fencing in riparian areas; and $0.50 for electric fence on fiber posts.

Organic erosion control fabrics used to protect seedlings and reduce surficial erosion typically cost between $2 and $3 dollars a square yard to buy and another $2 to 3 dollars a square yard to install. Installation includes key trench construction, backfilling, and staking as per manufactures recommendations. Browse protection and mulch cards can add an additional $1 to $2 dollars per tree installed. Temporary irrigation systems can run as high as $6,000 per acre for large areas. In some areas this cost can be reduced somewhat if irrigation lines and sprinklers can be rented.

Alternative water source development costs for livestock excluded from the stream vary significantly depending on method. Examples of approximate installed costs include:

- 2 ft deep fiber tanks - $1.10 per gallon;
- 750 gallon troughs - $800;
- Pipelines from spring to tank including 1" diameter pipe, backhoe-dug trench, valves, and fittings - $2.50 LF.
- Nose pump - Livestock pump own water. Can lift water 26 feet vertically, and 126 feet horizontally. $325 (this includes required foot valve and platform) (www.nosepump.com)

9 MONITORING

Plant growth and mortality should be monitored annually, at a minimum, during the growing season when identification of plant species is easiest. During the first year, and in arid areas, monitoring should be more frequent perhaps immediately following germination in the spring and again in late summer to identify and correct any problems early on. The objectives of a monitoring plan should be clearly specified, consistent with project goals, and linked to project maintenance. The monitoring plan should indicate the methods used to evaluate plant establishment and growth relative to design criteria (see Stream Habitat Restoration Guidelines, Chapter 5.3.4, *Design Criteria*). Often descriptive monitoring data is sufficient to evaluate project success, identify problem areas, compare effectiveness of different treatments and provide guidance for subsequent maintenance. Photo points are a very inexpensive, simple, and useful technique for monitoring riparian zone recovery [30,31]. However, depending on the monitoring objective, quantitative data may be required. If so, care should be taken to determine the minimum sample size necessary to draw statistically valid conclusions. Following are additional recommendations:

- Monitoring of plantings is sometimes complicated by the fact that installed plants may be obscured by naturally colonizing plants. If this is expected, it may be beneficial for success criteria to be achieved with a combination of installed *and* naturally colonizing vegetation, rather than simply requiring survival of a minimum percentage of installed plants.
- Use of reference sites to compare to the restored sites is encouraged.
- If experimental techniques are used, a sufficient portion of a budget should be set aside for monitoring, and quantitative monitoring may be justified to document the advantages/disadvantages of the technique.
- On sites where herbicides are applied, the monitoring area should include adjacent areas within "drift range" of herbicide application.
- Monitoring for the effectiveness of landuse changes such as changes in grazing strategy, complete cattle exclusion, or changes in mowing frequency along an urban stream corridor may consist of seasonal site visits summarized in photo points and a brief

memo.
- All monitoring activities should identify threats to project success.
- Monitoring frequency will depend on specific restoration objectives and performance criteria, and may range from once a year to several times during the first one or two growing seasons. In some cases more intensive annual monitoring events may be supplemented by more frequent and qualitative site visits.
- For specific details on vegetation monitoring, including monitoring methods, monitoring frequency refer to the *Monitoring Considerations* appendix and Elzinga et al.[32].

Determining the success of riparian restoration projects may require monitoring for longer than project budget and management scenarios allow[5]. For example, herbaceous groundcover may recover in a few years or less, while development of a woody canopy can require decades or centuries for full recovery. While decades of project monitoring is desirable, it is often beyond an individual project's scope. Three to five years of monitoring is a realistic goal and long enough to determine if the restoration effort is likely to have the desired results. Refer to the *Monitoring Considerations* appendix for more information on developing a monitoring plan.

10 MAINTENANCE

Where establishment of riparian vegetation is critical to long-term streambank stability and habitat restoration, planting is just the beginning. A commitment to maintain the site until the plants get established is critical. Establishment times vary, but three years is considered about average with some commitments out to ten. Young trees and shrubs are very susceptible to drought, competition from other vegetation for moisture, light, space, and nutrition, and browsing/trampling by livestock and wildlife. During the first three years following planting, inspect the area annually (perhaps more in arid areas) to identify problems and implement repairs/modify management strategies, as needed. Be sure that those responsible for on-site maintenance are aware of the commitment and the location of all new plantings. There have been numerous examples of park, golf course, utility company, and other maintenance crews mowing down new plantings because they were unaware of their existence or intension.

Maintenance may include:
- *Irrigation*. Drought is a particular hazard to young plants due to their small tissue mass and root system. Plants that are not rooted in moist soils will need to be watered regularly throughout the dry season until the fall rains. Watering needs depend on site conditions, soil texture and planting depth. Watering heavily and infrequently, as opposed to frequent shallow watering, encourages deep root growth, which increases drought tolerance. In general, plants should be watered for at least the first growing season, and watering should only be stopped when the plants develop root systems capable of reaching a depth where the soils are permanently moist. This normally occurs by the end of the second growing season[4].

- *Browse Protection*. Foliar repellents (such as DeerAway™), bud caps, mesh tubing or stem screens (http://www.for.gov.bc.ca/hfp/forsite/progress/may1997/mammal~1.htm#one) may protect highly palatable species such as dogwood and willow from large mammal browse damage. In cases of heavy ungulate use fencing may be the only option. However, consider that all these methods may be less effective in floodprone areas subject inundation and hydraulic forces of flowing water.

- *Fences*. Livestock fences should be inspected and maintained to prevent livestock access to the planted area. Even small numbers of livestock or short-duration grazing can severely reduce plant survival. Although grazing may not impact non-palatable species, they are subject to other impacts such as trampling[4]. Temporary or permanent fences may also be needed in areas subject to heavy foot and pet traffic such as at parks. Chaney et al.[33] provide additional information on the benefits of fencing, rotational grazing, and livestock access limitations. Keep in mind that fences that are capable of excluding domestic livestock are not normally effective at excluding deer, elk or moose. Exclusion fences for these species must be significantly more robust and taller.
- *Protection from Small Mammal Damage*. Aluminum foil, arbor guards or photodegradable, plastic-tube, plant protectors may be needed to protect plants from rodent girdling, a common problem in open pastures and meadows. Aluminum foil has proved effective provided it is checked and replaced as needed. Plastic-tube plant protectors shield plants from direct sun and wind exposure; they retain moisture, creating a humid microclimate, and they protect plants from mowers. Chicken wire fencing may be needed to protect plants from beaver and muskrat during the plants' critical period of establishment.
- *Plant replacement*. Replacing plants that died may be important, but not if the cause of the stress has not been eliminated or if naturally colonizing plants are meeting monitoring objectives.
- *Weed Suppression*. Weed suppression may be needed, but should focus on controlling or eradicating long-lived, perennial weeds that are likely to degrade the site or violate state/county regulations. If planting was in a pasture or other heavily vegetated site, vegetation surrounding the plant should be periodically removed or mown to maintain the three-foot-diameter open area surrounding each plant. Mowing twice a year during the first three growing seasons is generally recommended – once in the spring and once in midsummer. On sites where reed canary grass grows, a third mowing in the fall right down to the ground is sometimes recommended to reduce the amount of grass that comes back the following spring. Consult your local or state weed control board for more information concerning weed control and removal or see the excellent reference by Tu et al.[20].

Riparian Restoration and Management Table 7: Woody plants recommended for revegetation of riparian corridors

Species		Indicator Status(1)	Max. Height(2) (ft)	Elev. Range (3)	Soil Moisture (4)					Light Req (5)	Rooting Character (6)	Comments
Common Name	**Scientific Name**				A Dry	B	C	D	E Wet			
TREES												
Grand fir	Abies grandis	NOL	100-250	l-h	•	•	•			sn-pt sh	deep taproot; many lateral branches	Best conifer for soil binding roots; prefers deep, well-drained, alluvial soils; seedlings are shade tolerant; drought tolerant
Noble fir	Abies procera	NOL	90-250	m-h	•	•	•			sn		
Douglas maple	Acer glabrum var. douglasii	FACU†	10-25	l-m	•	•	•			sn-pt sh	deep, lateral	Found along canyons, rocky cliffs, forest openings on mountain slopes, moist but well-drained streambanks, floodplains, avalanche tracks; requires well-drained soils
Big-leaf maple	Acer macrophyllum	FACU †	80-100	l	•	•	•			sn-pt sh	deep, wide	Good soil binding properties; grows in a variety of soils but seldom in saturated soil; fast growing; flood tolerant
Red alder	Alnus rubra	FAC †	40-80	l-m		•	•	•		sn	shallow, strong, lateral, spreading, fibrous	Does well on disturbed sites in a variety of soils; fast grower; N fixer; high survival from "pull-ups"; tolerates drought, flooding, or brackish conditions; relatively short-lived (60-70yr); subject to wind throw, broken crowns, ice damage; west of Cascades only
Sitka alder/ Slide alder	Alnus sinuata	FACW †	25	m-h			•	•		sn-pt sh		Moderate flood and deposition tolerance; does well on disturbed sites and alluvial floodplains in rocky or gravelly soil; prefers some shade or north facing aspect
Mountain alder/ Thinleaf alder	Alnus tenuifolia	FACW	30-40	l-h			•	•		sn		Most common alder of the interior; usually found in pure stands; east of Cascades only

Pacific madrone	Arbutus menziesii	NOL	50-90	l	• •	sn	deep tap root, wide, tenacious	Evergreen; drought and salt spray tolerant; sensitive to air pollution; found along coast on rocky sites or coarse textured soils; slow grower; west of Cascades only
Water birch	Betula occidentalis	FACW	20-50	l-m	• •	sn-pt sh	shallow to deep, spreading	Moderate flood and deposition tolerance; east of Cascades only
Paper birch	Betula papyrifera	FACU	60-70	l-m	• • •	sn-pt sh	deep	Fast growing; prefers sandy loam but tolerates poorly drained soils; tolerates periodic flooding and drought, acid soils; does well on disturbed sites
Pacific dogwood	Cornus nuttallii	NOL	10-65	l	• • •	pt sh-sh		Prefers deep well-drained soils high in nitrogen; found in open to fairly dense mixed forests; west of Cascades only
Oregon ash	Fraxinus latifolia	FACW	60-80	l	• • •	sn-pt sh		Prefers flat loamy soil; tolerates standing water early in growing season; west of Cascades only
Western crabapple	Malus fusca	FAC+ †	15-40	l	• • •	sn	shallow, spreading	Forms dense thickets; does well in a variety of soils and near salt water, sloughs, and estuaries; prefers acid soils; tolerant of prolonged soil saturation; west of Cascades only
Sitka spruce	Picea sitchensis	FAC	100-230	l	• • •	sn-sh	shallow-moderate, dense	Tolerates flooding, salt spray, acid soil; found on alluvial floodplains, marine terraces, recent glacial outwash, avalanche tracks, and old logs or mounds in boggy sites; subject to blowdown in areas of high water table; west of Cascades only
Lodgepole pine	Pinus contorta var. latifolia	FAC-	100- 120	m-h	• • • •	sn		Found in saturated to excessively well-drained soils; tolerant of low nutrient soils; highly adaptable

Shore pine	Pinus contorta var. contorta	FAC-	45-60	l-m	• • • •	sn	deep, wide	Highly adaptable; found in dunes and bogs to rocky hilltops and exposed outer shorelines; coastal; tolerates salt and low-nutrient soils
Ponderosa pine	Pinus ponderosa	FACU-	150-200	l-m	• •	sn		Dry gravelly soils; drought tolerant once established; mainly east of Cascades
*Black cottonwood	Populus balsamifera ssp. trichocarpa	FAC †	100-200	l-m	• • •	sn	fibrous, shallow-deep and widespread, extensive	Fast grower; susceptible to root rot, windthrow; tolerates seasonal flooding; grows well in a variety of soils
Quaking aspen	Populus tremuloides	FAC+	30-80	l-h	• • •	sn	shallow, extensive, invasive, spreading roots send up shoots	Forms dense groves; moderate drought and salinity tolerance; fast growing; prefers sandy loams
Bitter cherry	Prunus emarginata	FACU	40-60	l-m	• • •	sn-pt sh	spreading; root system sprouts new growth	Prefers well-drained slightly alkaline soils; establishes easily on disturbed sites; can form thickets; may be poisonous to livestock
Douglas fir	Pseudotsuga menziesii	NOL	75-300	l-m	• • •	sn-pt sh	tap-modified tap; shallow-deep and widespread	Pioneering species; good soil binding roots; fast grower; needs good drainage; does best in deep, moist, sandy loams; poorest in gravelly soils; potential for wind throw in thin or disturbed soils
Oregon white oak	Quercus garryana	NOL	75	l	• • •	sn	deep tap root	Typically found on gravelly outwash prairies and floodplains; slow growing
Cascara	Rhamnus purshiana	FAC-	25-35	l	• • •	sn-sh	moderately deep tap root	Good soil binding qualities; grows well on disturbed sites; prefers loamy soils, shaded southern aspects and swampy clearings; sensitive to air pollution
*Peachleaf willow	Salix amygdaloides	FACW		l	• • •	sn	fibrous	Deposition and flood tolerant; moderate salinity tolerance; found on streambanks in plains and foothills; east of Cascades only

*Pacific willow	Salix lasiandra	FACW+ †	20-40	l-m	• • •	sn	fibrous, moderately deep and widespread	Flood and deposition tolerant; grows well on sandy, gravelly, or loamy soils; found on riverbanks, floodplains, lakeshores, wet meadows; often standing in quiet, shallow river backwaters; generally found in pure stands
*Scouler willow	Salix scouleriana	FAC †	10-40	l-m	• • •	sn-pt sh	fibrous, moderately deep and widespread	Flood, drought, and deposition tolerant; moderate salinity tolerance; prefers gravelly soil; does not grow in standing water
Pacific yew	Taxus brevifolia	FACU-	15-45	l-h	• • •	pt sh-sh	deep	Very slow growing; prefers loamy soils under canopy of large trees; foliage is poisonous to livestock
Western red cedar	Thuja plicata	FAC	150-210	l-m	• • •	sn-sh	shallow, widely spreading	Tolerates seasonal flooding and perennially-saturated soils; seedlings require some shade; tends to be wind-firm except in very wet sites; prefers loamy soils
Western hemlock	Tsuga heterophylla	FACU-	120-180	l-m	• •	sn-sh	shallow-moderate	Does best on deep, moist, well-drained soils; requires high organic content in soil; thrives in dense shade; seedlings are often dried out by full sun; susceptible to wind throw

Species		Indicator Status(1)	Max. Height (2) (ft)	Elev. Range (3)	Soil Moisture (4)	Light Req (5)	Rooting Character (6)	Comments
SHRUBS/ GROUNDCOVER								
Vine maple	Acer circinatum	FACU+ †	15-25	l-m	• • •	sn-sh	fibrous, moderately deep, spreading	Needs canopy shade or lots of moisture; excellent soil binding qualities; prefers sandy loam; mostly west of Cascades

Serviceberry	Amelanchier alnifolia	FACU	6-25	l-h	• •	sn-pt sh	deep, spreading	Edge-loving; very drought tolerant; thicket forming; prefers well-drained, loamy soils but found on dry gravelly and rocky sites; good stabilization value; sensitive to competition around roots; slow to establish
Kinnikinnik	Arctostaphylos uva-ursi	FACU-	1	l-h	• •	sn	fibrous, shallow, dense, extensive, highly branched	Slow grower; evergreen; likes dry stony soil; tolerates salt spray; prefers slightly acidic soil
Tall Oregon grape	Berberis aquifolium	NOL	3-10	l	•	sn-pt sh	deep	Slow grower; thicket forming; grows in variety of soils; found in drier (often rocky) sites than *B. nervosa*; evergreen
Low Oregon grape	Berberis nervosa	NOL †	2	l-m	•	pt sh-sh		Slow grower; thicket forming; good on slopes; grows in a variety of soils; evergreen; west of Cascades only
Hackberry	Celtis reticulata		30	l		sn		Limited range, mostly in southeast WA; found on edge of streams and adjacent bluffs
*Red-osier dogwood	Cornus stolonifera	FACW †	6-20	l-m	• • •	sn-sh	shallow, strong, lateral, fibrous	Excellent soil binding qualities; thicket forming; grows in a variety of soils; takes full sun if has lots of moisture; tolerates seasonal flooding
Hazelnut	Corylus cornuta	NI †	5-20	l	• • •	sn-sh	extensive, branching	Grows well in a variety of soils but prefers well-drained soil; intolerant of saturated soil
Black hawthorn	Crataegus douglasii	FAC †	3-20	l	• • •	sn-pt sh	shallow to deep, spreading	Excellent soil and streambank stabilizer; moderate deposition tolerance; thicket forming; well adapted to disturbed sites; prefers well-drained soils; resistant to beaver; not favored by deer/elk

Salal	Gaultheria shallon	NOL †	3-15	l-m	•	sn-sh	fibrous, shallow, dense	Slow to establish; grows in a variety of soils but prefers shade and rich soil; tolerates salt spray, low nutrient soils; good soil binding qualities; thicket forming
Ocean spray	Holodiscus discolor	NOL †	6-15	l	•	sn-pt sh	fibrous, moderate depth, spreading	Grows well on dry steep slopes; very drought tolerant; grows well on disturbed sites in a variety of soils including gravelly and rocky soils
Trumpet honeysuckle	Lonicera ciliosa	NOL	vine	l	•	sn-pt sh	shallow to moderate	
*Black twinberry	Lonicera involucrata	FAC †	3-15	l	• • •	sn-sh	fibrous, shallow, spreading	Takes full sun if has lots of moisture; tolerant of shallow flooding early in growing season; prefers loamy soils; fast growing; good soil binding characteristics
Mock azalea	Menziesia ferruginea	FACU+	2-7	m	• •	pt sh-sh		Found in moist conifer woods with acid humus, slopes, and streambanks, edges of coastal sphagnum bogs
Sweetgale	Myrica gale	OBL	2-7	l	• •	sn		Found in freshwater wetlands, bogs, and lakes, upper fringes of salt marshes and tidal flats; thicket forming
Indian plum	Oemleria cerasiformis	NOL †	5-15	l	• •	sn-pt sh	fibrous, shallow, spreading	Prefers some shade; grows well in a variety of soils but intolerant of saturated soil: west of Cascades only
Oregon boxwood	Pachystima myrsinites	NOL	1-3	l-m	• •	sn-sh		Found on shallow, gravelly clay and silt loam; prefers light to deep shade, moist atmosphere; evergreen
Mock orange	Philadelphus lewisii	NOL	3-12	l-h	• • •	sn-pt sh	spreading, fibrous	Fast vigorous grower; grows well in loamy to rocky, poor soils
*Pacific ninebark	Physocarpus capitatus	FAC+ †	6-13	l-m	• • •	sn-pt sh	fibrous, shallow, lateral	Fast vigorous grower; excellent soil binding qualities; grows well in a well-drained loamy to rocky soils; mostly west of Cascades

*Mallow ninebark	Physocarpus malvaceous	NOL	2-6	1-m	•	sn		Tough, tenacious shrub; prefers sandy to silty clay loam, dry canyon bottoms, rocky slopes; thicket forming; east of Cascades only
Choke cherry	Prunus virginiana	FACU	10-20	l	• •	sn-pt sh		Moderate salinity and drought tolerance; tolerates slightly saline soil; good soil binding characteristics; forms dense stands
Smooth sumac	Rhus glabra	NOL	3-20	l	•	sn	Rhizomat-ous	Prefers open habitats; forms loose thicket; east of Cascades only
Golden currant	Ribes aureum	FAC+	6	l	• • •	sn-pt sh	spreading	East of Cascades only
Squaw currant	Ribes cereum	FAC	2-4	l	• • •	sn-pt sh		East of Cascades only
Mountain gooseberry	Ribes irriguum		6	m	• • •			Found along streams in mountains of eastern Washington
Black gooseberry/ Swamp gooseberry	Ribes lacustre	FAC+ †	2-7	l-h	• • •	pt sh-sh		Drought tolerant; grows in a variety of soils but prefers loamy soils; often grows on rotting wood and spring seepage sites that become dry in late summer; NOTE: is alternate host for White Pine Blister Rust—may not be an issue if it's naturally abundant in area
Red-flowering currant	Ribes sanguineum	NOL	5-10	l	•	sn-pt sh	fibrous, shallow	Prefers dry loamy soils; found on rocky slopes, disturbed sites, and dry open woods; intolerant of saturated soils
Wood rose/ Baldhip rose	Rosa gymnocarpa	FACU	2-6	l-m	• •	pt sh		Tough, hardy; extremely drought tolerant; prefers rocky soils; excellent soil binding characteristics
*Nootka Rose	Rosa nutkana	FAC- †	2-10	l	• • •	sn-pt sh	fibrous, shallow	Rapid volunteer on damp soil; thicket forming; tolerates salt spray, saturated soils, or inundation for much of the growing season; excellent soil binding characteristics; prefers nitrogen-rich loamy soils

Clustered Rose/ Swamp Rose	Rosa piscocarpa	FACU †	6	l	• •	sn-pt sh		Tolerates infertile soils; prefers loamy soils; excellent soil binding characteristics; west of Cascades only
Wood's Rose/ Prairie Rose	Rosa woodsii	FACU †	6	l-m	• •	sn-pt sh		Prefers moist, well-drained clay loam, sandy loam, or sandy soil; thicket forming; east of Cascades only
Thimbleberry	Rubus parviflorus	FACU+ †	2-10	l-h	• •	sn-pt sh	fibrous, shallow	Found along road edges, clearings, avalanche tracks, and shorelines, or under light forest canopy; drought tolerant; intolerant of saturated soils; good soil binding qualities; thicket forming; prefers sandy loam rich in humus
*Salmonberry	Rubus spectabilis	FAC †	6-15	l-m	• • •	pt sh-sh	fibrous, shallow	Well-adapted to eroded or disturbed sites; <u>takes full sun if lots of moisture</u>; spreads rapidly; dense thickets can inhibit native tree establishment; mostly west of Cascades
*Under-green willow	Salix commutata	OBL †	8	m-h	• •	sn		Edges of rivers, lakes, wetlands, gravelly benches, fresh alluvial and morainal materials, open forests
*Drummond willow	Salix drummondiana	FACW †	12	l-h	• • •	sn	shallow to deep	East of Cascades only
*Coyote willow	Salix exigua	OBL †	15	l	• •	sn	shallow, widespread	Colonizes coarse gravel and bar islands; usually grows partly submerged; thicket forming; east of Cascades only
*Columbia R willow	Salix fluviatilis	OBL †	13	l	• •	sn		Prefers sand, gravel, or silt; banks of Columbia River only
*Geyer willow	Salix geyeriana	FACW+ †	15	l-h	• • •	sn	shallow to deep	Likes inundation, sluggish water, wet meadows; deposition tolerant
*Hooker's willow	Salix hookeriana	FACW - †	20-30	l	• • •	sn	fibrous, moderately deep	Naturally found <5mi from coast; salt spray tolerant; sandy, gravelly, or loamy soils
*Arroyo willow	Salix lasiolepis	FACW †	35	l	• • •	sn	shallow to deep	Flood and deposition tolerant; prefers coarse textured soils; east of Cascades only

*Heart-leaf willow	Salix rigida	OBL †	12	l-m	• •	sn		Generally uncommon, except on gravel and sandbars along major rivers
*Sitka willow	Salix sitchensis	FACW	3-26	l-m	• • •	sn	fibrous, moderately deep and widespread	Tolerates seasonal flooding; prefers sandy or loamy soils; found in clearings, avalanche tracks, on edges of streams, lakes, wetlands, moist forests
*Blue elderberry	Sambucus caerulea	FAC-	20	l	• •	sn-pt sh		Good soil binding qualities; grows well in a variety of soils; moderate salinity tolerance; favors moist soils of valley bottoms and sunny open slopes; in arid areas, restricted to streambanks and river bottoms
*Red elderberry	Sambucus racemosa	FACU †	6-20	l-m	• •	sn-pt sh	fibrous; strong adventitiou s roots; spreading; moderate	Rapid grower; grows well on disturbed sites in a variety of soils; found on streambanks, swampy thickets, moist clearings, open woods; moderate salinity tolerance
Cascade mountain ash	Sorbus scopulina	NI	20	m-h	•	sn		
Sitka mountain ash	Sorbus sitchensis	NOL	12-20	m-h	• •	sn		Found on streambanks, forest openings, edges of meadows or rock slides; prefers rich well-drained soils
*Douglas spirea	Spiraea douglasii	FACW †	3-6	l-h	• • •	sn	extensive, fibrous, shallow	Forms dense thickets; spreads quickly and aggressively; tolerates seasonal inundation; prefers loamy soils
Creeping snowberry	Symphoricarpos mollis	NOL †	1.5	l-m	•	pt sh	extensive, branching, fibrous	Forms dense thickets
Snowberry	Symphoricarpos albus	FACU †	2-6	l-m	• •	sn-pt sh	extensive, branching, fibrous, shallow	Forms dense thickets; tolerates high winds, some flooding while dormant; excellent soil binding characteristics; prefers loamy well-drained soils
Oval-leaf huckleberry	Vaccinium ovalifolium	UPL	2-6	l-m	•	pt sh-sh		Prefers loamy acid soils; found in bogs, moist coniferous forests

Evergreen huckleberry	Vaccinium ovatum	NOL	2-15	l-m	●	pt sh-sh	fibrous, shallow	Slow growing; tolerates salt spray; prefers mature shade, slightly acidic rocky or gravelly soils; evergreen; coastal
Wild cranberry	Vaccinium oxycoccos	OBL	1	l-m	● ●	pt sh		Boggy sites; vine-like; evergreen
Red huckleberry	Vaccinium parvifolium	NOL	3-13	l	●	pt sh-sh	moderate	Prefers loamy, acid soils or rotting wood; requires lots of organic matter; west of Cascades only
Highbush cranberry	Viburnum edule	FACW	2-12	l-m	● ● ●	sn-pt sh		Found in moist woods, wetland margins, streambanks, river terraces
Oregon viburnum	Viburnum ellipticum	NOL	10	l	● ●	sn-pt sh		Found in thickets and open woods; west of Cascades only
Wild guelder rose	Viburnum opulus	NOL	10		● ● ●	sn-sh	strong adventitious roots	Found in moist woods

<u>FOOTNOTES</u>

* Indicates plant propagates well from hardwood cuttings planted directly in the field, according to Leigh[21] and Myers[13] .

(1) **Indicator Status** = plant indicator status (UPL, FAC, etc.) From USFWS (Reed 1988, 1993 supplement[34]). A positive (+) sign, when used with indicators, indicates “slightly more frequently found in wetlands” and a negative (-) sign, when used, indicates “slightly less frequently found in wetlands”. Species marked (†) indicate trees and shrubs tolerant of severe pruning (or grazing); these either stump sprout readily or sucker from roots.

- UPL Obligate upland: occurring almost exclusively in non-wetland environments.
- FACU Facultative upland: occurring primarily in non-wetland environments, but occasionally found in wetlands.
- FAC Facultative: occurring with approximately equal frequencies in wetlands and non-wetlands.
- FACW Facultative wetland: occurring primarily in wetland environments, but occasionally found in non-wetlands.
- OBL Obligate wetland: occurring almost exclusively in wetland environments.
- NI No indicator: there was insufficient data available to determine an indicator status.
- NOL Not on list: Species does not occur in wetlands anywhere in the United States. Therefore, it is not included in the National List of Plant Species that Occur in Wetlands[34].

(2) **Maximum Height** = the approximate height (feet) to which plants will grow under natural conditions with sufficient time. Mature height or the size at which plants begin to flower and produce seeds is substantially less in many species.

(3) **Elevation Range** = the elevations where the species commonly occurs. l=low, sea level to 2500 feet; m=med, 2500 to 4500 feet; h=high, above 4500 feet. All elevations are variable depending on microclimates.

(4) **Soil Moisture** = Plant associations recommended for various soil moisture levels:

A. Very droughty soils: use UPL and FACU species. These conditions may be expected in porous or well-drained (sandy) soils or high on the bank, especially on south or west facing banks with little shade.

B. Droughty soils: use mostly UPL and FACU species; FAC species may be used occasionally if site conditions are somewhat moist. These soils occur in areas similar to very droughty soil, but where moisture retention is better (e.g., less sandy soils, shade, and north or east facing banks).

C. Moderate soils: use FACU, FAC, and FACW species. Much of Western Washington has these soils. They are loamy soils with some clay, on level areas to steep slopes. They may be shallow soils over hardpan, or areas where seeps are common. Plant selection should consider microclimatic conditions including seeps, slope, aspect, etc. Steeper slopes, for example, will be drier than soils because of water run off.

D. Wet soils: use mostly FAC and FACW species; OBL species can be used in particularly wet areas as long as the soil is not compacted. They retain water rather than allowing it to run off after rain, and are moist to wet for most of all of the year. Because these areas have minimal slope and typically slow-moving streams, erosion is seldom a problem.

E. Very wet soils: use FACW and OBL species. These soils may be found along meandering rivers and streams with low banks. There is typically a high water table that allows the development of organic soils (peats and mucks). They are not well suited to large woody vegetation, as trees tend to blow over. Dense thickets of shrubs and small trees are common. Because these areas have minimal slope and typically slow-moving streams, erosion is seldom a problem.

(5) **Light Requirement**: sn = full sun, pt sh = part shade, sh = full shade

(6) **Rooting Character**: “Fibrous” indicates that plant lacks a central root; root mass is composed of fibrous lateral roots. “Tap” indicates that plant has a stout, central main root. Shallow, moderate, and deep refer to relative rooting depth. Note that depth and character of roots are determined by soil conditions as well as species characteristics.

11 EXAMPLES

Riparian Restoration and Management
Figure 6: Contrast in plant communities in areas from which livestock are excluded and areas from which they are not.

Riparian Restoration and Management
Figure 7: Natural recovery of vegetation at Asotin Creek 5 years after fencing livestock from the stream, Asotin County, Washington.

Riparian Restoration and Management
Figure 8: Revegetation project on Harrison Creek, Skagit County, Washington. Site was dominated by reed canary grass. Strips of ground were disked prior to planting to facilitate maintenance. Tubes were used to protect plants from small mammals.

Riparian Restoration and Management
Figure 9: Revegetation project in O'Grady Park in King County, Washington. Site was dominated by reed canary grass. Plantings occurred in patches across the site. Each patch was heavily mulched and surrounded by deer fence.

Riparian Restoration and Management Figure 10: Revegetation project in Palouse County, Washington.

(a)

(b)

Riparian Restoration and Management Figure 11: (a) New growth emerging from live cutting; (b) Bare-root Ponderosa pine.

12 Glossary

Scarification **–** A method of soil preparation that consists of exposing or loosening patches of mineral soil through mechanical action to create favorable conditions for the establishment of seedlings and seed.

Amendment – Soil amendments organic matter, mineral, or other substances added to the soil to improve conditions for plant growth.

Solarization **–** Soil solarization, also referred to as solar heating, is a non-chemical method used to kill soil borne pathogens and weed seeds using mulch or transparent polyethylene tarps during the hot season. Used mostly as a pre-planting soil treatment. See Katan et al. 1987[35] for additional information.

Channel migration zone **–** The area within which a stream channel has or may migrate laterally under its current geomorphic regime. Commonly defined by historic meander limits or meander belt width[36]

Mass wasting - a general term for a variety of processes by which large masses of rock or earth material are moved down slope by gravity.[1]

13 References

13.1 Additional Reading

Crawford R. 2001. Initial riparian and wetland vegetation classification and characterization of the Columbia Basin in Washington. Washington Natural Heritage Program, Washington Department of Natural Resources, Olympia, Washington. 83 pp.

Gecy, J. L., and M. V. Wilson. 1990. Initial establishment of riparian vegetation after disturbance by debris flows in Oregon. American Midland Naturalist 123: 282-291.

Johnson, A. W. and J. M. Stypula (editors). 1993. Guidelines for Bank Stabilization Projects in the Riverine Environments of King County. King County Department of Public Works, Surface Water Management Division, Seattle, Washington.

Katan, J., A. Grinstein, A. Greenberger, O. Yarden & J. E. DeVay. 1987. First decade (1976-1986) of soil solarization (solar heating)-A chronological bibliography. Phytoparasitica 15: 229-255.

Prichard, Don. 1993. Riparian Area Management: Process for Assessing Proper Functioning Condition. U.S. Department of Interior, Bureau of Land Management Proper Functioning Condition Work Group. TR 1737-9 1993. BLM/SC/ST-93/003+1737. 51 pp.

Roni P., T. Beechie, R. Bilby, F. Leonetti, M. Pollock, and G. Pess. 2002. A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds. North American Journal of Fisheries Management 22: 1-20.

13.2 Cited References

[1] Slaney, P. A. and D. Zaldokas (editors). 1997. Fish Habitat Rehabilitation Procedures. Watershed Restoration Program, Ministry of Environment, Lands and Parks, Vancouver, British Columbia.

[2] Knutson, K. L. and V. L. Naef. 1997. Management Recommendations for Washington's priority habitats: riparian. Washington Department of Fish and Wildlife, Olympia, Washington. 181 pp.

[3] Kauffman, J. B., R. L. Beschta, N. Otting, and D. Lytjen. 1997. A ecological perspective of riparian and stream restoration in the western United States. Fisheries 22(5): 12-24.

[4] Cowx, I. G. and R. L. Welcomme. 1998. Rehabilitation of Rivers for Fish. Published by arrangement with the Food and Agriculture Organization of the United Nations by Fishing News Books, Oxford, England. 260 pp.

[5] Kauffman, J. K., M. Mahrt, L. Mahrt, and W. D. Edge. 2001. Wildlife of Riparian Habitats. Chapter 14 *In*: Johnson, D.H., and T.A. O'Neil. Wildlife-Habitat Relationships in Oregon and Washington. Oregon State University Press, Corvallis, Oregon. pp. 361-388.

[6] Junk, W. J., P. B. Bayley, and R. E. Sparks. 1989. The flood pulse concept in river-floodplain systems. Canadian Special Publications in Fisheries and Aquatic Sciences 106: 110-127.

[7] Briggs, Mark K. 1996. Riparian Ecosystem Recovery in Arid Lands: Strategies and References. The University of Arizona Press, Tucson, Arizona. 159 pp.

[8] Morrison, M. L. 2002. Wildlife Restoration: Techniques for Habitat Analysis and Animal Monitoring. Society of Ecological Restoration. Island Press, Washington D.C.

[9] Saldi-Caromile, K., B. Barnard, K. Buchanan. 2001. Channelized Stream Restoration: Documentation and Evaluation of Ten Restoration Projects Constructed by Jobs for the Environment Grantees, DRAFT DOCUMENT. Washington Department of Fish and Wildlife, Olympia, Washington.

[10] Leigh, M. 1997. Grow Your Own Native Landscape: A Guide to Identifying, Propagating, and Landscaping with Western Washington Native Plants. Washington State University Cooperative Extension, Thurston County, Washington.

[11] Thurston County Master Gardener Foundation. 1996. Northwest Native Plants Identification and Propagation for Revegetation and Restoration Projects. Washington State University Cooperative Extension, Thurston County, Washington.

[12] The Native Plant Source Directory. Hortus West Publications, Wilsonville, Oregon.

[13] Myers, R. D. 1993. Slope Stabilization and Erosion Control Using Vegetation: A Manual of Practice for Coastal Property Owners. Publication 93-30. Washington State Department of Ecology, Shorelands and Coastal Zone Management Program, Olympia, Washington.

[14] Gray D. H. and R. B. Sotir. 1996. Biotechnical and Soil Bioengineering Slope Stabilization. John Wiley & Sons, Inc., New York, New York. 378 pp.

[15] Ogle. D. G., J. C. Hoag, and J. D. Scianna. 2000. Users Guide to Description, Propagation and Establishment of Native Shrubs and Trees for Riparian Areas in the Intermountain West. Technical Note Plant Materials No. 32. USDA-Natural Resources Conservation Service, Boise, Idaho and Bozeman, Montana.

[16] Forest Practices Code of British Columbia. 1997. Soil Rehabilitation Guidebook. Appendix 2 – Revegetation Techniques. www.for.gov.bc.ca/tasb/legsregs/fpc/FPCGUIDE/soilreha/app2.htm

[17] Mark Stannard, personal correspondence, July 2002.

[18] Shiechtl, H. M. and R. Stern. 1994. Water Bioengineering Techniques for Watercourse, Bank and Shoreline Protection. Blackwell Sciences, London, England. 189 pp.

[19] Oswald, J., L. Brown, and P. Peterson. 1995. Water Crystals for Moisture Retention. Pacific Northwest Conservation Tillage Systems Information Source, On-Farm Testing Report. http://pnwsteep.wsu.edu/onfarmtesting/1995/tocamendments.htm

[20] Tu, Mandy, Callie Hurd, and John Randall. 2001. Weed control methods handbook: tools and techniques for use in natural areas. The Nature Conservancy, Wildland Invasive Species Program. http://tncweeds.ucdavis.edu/handbook.html

[21] Leigh, Michael. 1997. Grow Your Own Native Landscape: A Guide to Identifying, Propagating, and Landscaping with Western Washington Native Plants. Washington State University Cooperative Extension. 132 pp. http://cru.cahe.wsu.edu/CEPublications/misc0273/misc0273Abstract.htm

[22] Stannard, M., L. Holzworth, J. Scianna, D. Ogle, and E. Sunleaf. 2002. History, Biology, Ecology, Suppression and Revegetation of Russian-olive sites. USDA-NRCS, Spokane, Washington, Boise, Idaho, and Bozeman, Montana. TN-47. 14 pp. (ID# 2910) http://plant-materials.nrcs.usda.gov/technical/publications/invasive.html

[23] Hoag, C. 1993. How to Plant Willows and Cottonwoods for Riparian Rehabilitation. Technical Note Plant Materials No. 23. USDA-Natural Resource Conservation Service, Boise, Idaho.

[24] Johnson, A. W. and J. M. Stypula (editors). 1993. Guidelines for Bank Stabilization Projects in the Riverine Environments of King County. King County Department of Public Works, Surface Water Management Division, Seattle, Washington.

[25] Drake, L. 1998. Planting Deep Willow Cuttings Via Hydraulic Jetting. Department of Geology, University of Iowa, Iowa City, Iowa. www.geology.uiowa.edu/faculty/drake/willow.html

[26] U.S. Department of Agriculture. 1994. The Stinger. Technical Notes No. 6. USDA-Soil Conservation Service, Boise, Idaho.

[27] U.S. Department of Agriculture. 1996. Streambank and Shoreline Protection, NRCS Engineering Field Manual, Part 650.

[28] Hoag, J., B. Simonson, B. Cornforth, and L. St. John. 2001. Waterjet Stinger: A Tool to Plant Dormant Unrooted Cuttings of Willows, Cottonwoods, Dogwoods and Other Species. Riparian Wetland Project Information Series No. 17. U.S. Department of Agriculture, Natural Resources Conservation Service, Plant Materials Center, Aberdeen, Idaho. 13 pp.

[29] Hoag, C. J. 2000. Costs and considerations of streambank bioengineering treatments. Riparian/Wetland Project Information Series No. 15. USDA-NRCS, Plant Materials Center, Aberdeen, Idaho.

[30] Edelen, W.J., and W.A. Crowder. 1997. Photography: A Basic Monitoring Technique for Riparian Ecosystem Projects. Technical Note #33. U.S. Department of Agriculture, Natural Resources Conservation Service, Pullman Plant Materials Center, Pullman, Washington.

[31] Governor's Watershed Enhancement Board (GWEB). 1993. Photo plots: a guide to establishing points and taking photographs to monitor watershed management projects. Salem, Oregon. 16 pp.

[32] Elzynga, E. D. Salzer, J. Willoughby. 1998. Measuring and monitoring plant populations. Bureau of Land Management Technical Reference 1730-1. BLM National Business Center BC-650B, P.O. Box 25047, Denver, Colorado 80225. 492 pp.

[33] Chaney, E., W. Elmore, and W. S. Platts. 1993. Managing Change: Livestock Grazing on Western Riparian Areas. Produced for the U.S. Environmental Protection Agency by the Northwest Resource Information Center, Eagle, Idaho.

[34] Reed, P. B. 1993. 1993 Supplement to List of Plant Species that Occur in Wetlands: Northwest (Region 9). Supplement to Biological Report 88(26.9) May 1988.

[35] Katan, J., A. Grinstein, A. Greenberger, O. Yarden & J. E. DeVay. 1987. First decade (1976-

1986) of soil solarization (solar heating)-A chronological bibliography. Phytoparasitica 15: 229-255.

[36] Skidmore, P., P. Cooper, and K. Boyd. 1999. Methodology for determining meander corridor limits. *In*: Proceedings of the AWRA Annual Water Resources Conference, Seattle, Washington.